" NITROGEN MINERALIZATION FROM CATTLE MANURE, FILTERMUD, FACTORY ASH AND NITROGEN UPTAKE BY MAIZE (Zea mays) IN A GLASSHOUSE EXPERIMENT."

By

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MARCH, 1995

DEDICATION

To my family;

Husband : Joseph

Sons : James and John

Daughters : Moureen and Sheila

DECLARATION

This thesis is my original work and has not been presented for a degree in any other University.

RISPER A. AMOLO
Signature...................... Date...14/11/95...........

This thesis has been submitted for examination with my approval as a University Supervisor.

Dr. Nancy Karanja
Signature...Karanja...................... Date...15/11/95.....

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ABSTRACT

To reduce over reliance on inorganic fertilizers due to high prices, there is a need to increase utilization of organic input sources such as filtermud, which is a by-product of white sugar manufacture. Fresh filtermud(FM) is detrimental to crops and it takes long (> six months) to decompose under natural conditions. Supply of decomposed filtermud is limiting due to its high demand as its use is well established among farmers in the Kenyan sugar belt. Consequently, a study was conducted to improve filtermud quality through reduced curing time hence enhance nutrient release. The approach was: chemical characterization of filtermud, cattle manure and factory ash followed by laboratory incubation of filtermud mixed with factory ash and or mineral nitrogen at different ratios. Nitrogen uptake by maize was assessed through a glasshouse pot experiment. The laboratory incubation experiment was held for 12 weeks with sampling at 2 weeks interval; each time mineral nitrogen (NO_3^- and NH_4^+) forms were analysed. Miwani FM was strongly acidic with a pH value of 4.93 and relatively lower lignin content than that from Muhoroni and Chemelil. In terms of nitrogen release it was superior to that from Chemelil and Muhoroni, releasing 53% of nitrogen after 12 weeks. Regression analysis of nitrogen release versus material quality showed that there was a negative linear relationship between the % lignin content (r =-0.99), lignin + polyphenol to nitrogen ratio (r= -0.93), lignin to nitrogen ratio (r =-0.93) carbon to nitrogen ratio (r=-0.85) on nitrogen release; hence % lignin was predominant factor controlling

the nitrogen release. A maize crop was grown for 9 weeks in pots containing soils with FM from Miwani mixed with or without mineral nitrogen at the following rates; 0, 7.5, 15, 30 and 45 tha $^{-1}$; soil mixed with 100 kgNha^{-1} was included giving a total of six treatments. FM at 45 tha^{-1} ammended with mineral nitrogen at 9 kg N per ton of FM gave significantly ($P \leq 0.05$)) higher dry matter (19g/pot) and nitrogen uptake (13%) than the rest of the treatments. Therefore, for an inherently low fertile soil for example, cambisol 45tha^{-1} FM amended with mineral nitrogen at 9 kg N/ton of FM would be required to improve the fertility and hence nutrient availability. The study should be continued under field conditions for results to be conclusive.

CHAPTER 1

1.0 INTRODUCTION

1.1 Location and climate of sugarbelt

Nyando Sugarbelt falls in the Lake Victoria ecological zone of Kenya, and covers about 74,040 hectares (Rachilo et al., 1984; Thorp et al., 1960). It constitutes the major part of Kano plains and the continuous foot hills and valleys of Nyando escarpment in the North (Obara, 1976). The average annual rainfall is about 1297 mm per year around Kibos,1320 mm at Chemelil and 1520 mm at Muhoroni. Mean temperature decreases eastward from 23° C around Lake Victoria coasts to 20°C in the higher altitudes (Anon, 1975; Obara, 1976). The area is dominated by the agroecological zone LM_2 (Subhumid lower Midland zone).

1.2 Soils found in the sugar belt

The soils are primarily Vertisols, but Eutric Nitosols and Planosols are also found.The soils form the basis of well defined catena running from reddish soils on the higher slopes of the escarpment through Chemelil clay loams to the vertisols in the plains (Anon, 1975). According to Thorp et al., (1960) and Rachilo et al., (1984) the soils under cultivation are deficient in nitrogen and phosphates and in some areas potassium levels are also low. The soil pH ranges from slightly acid to slightly alkaline (pH 5.9 - 7.2).

Although major nutrients are low there are no reports of serious trace element deficiency and the soils have reasonably high base saturation and exchange capacities, hence would respond well to fertilizers. However, from the above reports it was recommended that fertilizers be used and in some cases farm yard manure and compost be used as these manures supply most plant nutrients as well as improving the soil structure as compared to inorganic fertilizers.

The major limitations of these soils are drainage, sodicity and fertility (Rachilo et al., 1984). In the sugar belt, apart from Chemelil, drainage is in a poor state resulting in water logging in most areas during heavy rains. A coordinated approach to drainage involving many farmers, rather than individual farmer, may solve drainage problem, thus improving cane productivity and to some extent cane quality (Anon, 1975).

1.3 Sugarcane

Sugarcane is the main cash crop in this region while sorghum, maize and grain legumes are grown as subsistence food crops. However, for satisfactory cane growth under rainfed conditions annual rainfall of about 1400 mm per year is required. But most cane growing areas in the region have unreliable and often deficient rainfall resulting in drought damage and poor yields (Odhiambo, 1978). Annual cane yields for a period of 10 years had been 61.6 tha^{-1} and in 1992 the yields were reduced to 56.4 tha^{-1} resulting into 8.4% yield reduction (Anon, 1992).

The years,1993/94 indicated the same trend although it was not documented. Some of the reasons for cane yield reduction were: shortage of funds for cane development, drought, poor cane husbandry and socio-economic factors. One of the socio-economic factors is absenteeism which is common in Muhoroni and Chemelil settlement schemes. Most farmers did not complete their migration to the sugar farms from their original areas, some settlers went back to their original areas due to climatic and as well as other socio-economic problems, hence often the affected farmers are absent from the farms, resulting in poor cane management. Other major problems are human diseases and malnutrition. The two are inter related because malnutrition leads to diseases infestation because the body resistance is low. Other diseases are malaria and typhoid that reduce energy, initiative and mental capabilities of cane growers. There has been government policy that cane growers intercrop grains legumes which mature within a short time (3 - 4 months) with the sugarcane in order to meet their protein requirements since majority cannot afford high value proteins like meat.

1.4 Organic soil inputs

Soil degradation is wide spread throughout the tropics especially in continuously cultivated crop land where current land management practices do not include the replenishment of plant nutrients to the soil (Okalebo et al., 1993). Under shifting cultivation the fallow period was used to restore physical conditions and the soil organic matter, the key factors which determine soil fertility improvement and maintenance (Anon, 1978a). Natural build up of soil fertility during a 3 year fallow period was adequate to support a good crop which produced yields comparable to that obtained in chemically fertilized fields (Ananda et al., 1991). Fallow length has been reduced considerably in many areas due to population pressure leading to decline in soil productivity (Bationo et al., 1991). The best means of maintaining soil fertility and productivity at optimum level is through periodic additions of properly processed organic materials in conjunction with mineral fertilizers. These organic materials can contribute substantial amounts of macro and micro nutrients for crop growth, in addition to improving the soil physical properties.

Use of organic materials for growing crops and improving soil productivity is an agricultural practice that has been followed in the Far East countries for centuries (Anon, 1978a). Until mineral fertilizers were introduced in the mid nineteenth century, organic materials in the form of compost and animal manures were the only source of plant nutrients. Dependence on inorganic materials begun to decline about 20 years ago during the era of the "Green Revolution" (Anon, 1978a); when the use of mineral fertilizers was intensified thus reducing use of organic materials considerably. In view of the world energy crisis and continuing rise in cost of mineral fertilizers and questions as to their future availability and safety to environment there is renewed interest in organic matter recycling to improve soil fertility (Anon, 1978a; Weeraratna, 1979; Warren, 1992). Some of the readily available organic resources in the study area are, filtermud (Pressmud or filter-cake), farmyard manure, compost, maize and rice straw, sugarcane trash and animal manures.

1.4.1 Filtermud

Filtermud, a by-product of white sugar manufacture, is the finest deposit obtained during the filtration and clarification processes of crushed cane. It consists of very fine fibre particles, soil solid and chemical substances. It is readily available from all sugar factories in Kenya. The annual production for the last 10 years (1982 - 1991) from five sugar factories (Mumias, Chemelil, Miwani, Muhoroni and Sony) was 187, 407 tons (Anon, 1991). This would give an estimate of about 2670, 1429 and 668 tons annually for nitrogen, phosphorus and potassium respectively given that filtermud contains 1.44% N (filtermud decomposed for 6 months and above) (Anyango, 1984); 0.77% phosphorus and 0.36% potassium (Mutanda, 1978). Extensive and efficient utilization of filtermud would save the country foreign exchange as annual fertilizers consumption is between 100,000 and 250,000 tons and this figure is expected to rise to 400,000 tons by 1993 (Anon, 1989). Use of filtermud would lead to about 47% saving on fertilizers, based on above estimate. Mutanda, (1978) reported 50% saving on fertilizers when filtermud is used.

Its use has been popular among the farmers in the sugarbelt. The only limitation is transport because it is bulky while large quantities are needed to supply the required plant nutrients. It has been used as a supplement to commercial fertilizers in the cane field for a long time (Donato et al., 1980). However, some factors limit its use, firstly, it cannot be used fresh because it has a burning effect on the young plants: Secondly, it is required in large amounts to supply the required plant nutrients. Hence savings in terms of fertilizers are minimised due to high labour requirements and transportation of the bulky materials, since fresh filtermud is bulky and murky. In some cases filtermud has compared fairly well with mineral fertilizers especially phosphates (Karim et al., 1974). Potassium (Prasad, 1974) and nitrogen (Alexander, 1972). Mutanda, (1978) reported 4.5, 22 and 1.8kg equivalent weight of filtermud to urea, single superphosphate and muriate of potash respectively. The extent of the farmers who use filtermud in the sugar belt is not known although the practice is well established. It takes six or more months for the fresh filtermud to decompose and become useful as organic fertilizer. This period is long considering that farmers cannot afford the inorganic fertilizers and to some extent the fertilizers are unavailable. Donato et al., (1980) reported that fresh filter cake in combination with factory ash in a 4:1 ratio by weight cured in 25 days through bacterial and fermentative or enzymatic processes. The final product did not show any detrimental effect to crops when used. A part from increasing yields on the farms, filtermud also improves soil physical conditions especially the structure and tilth (Songambele, 1982) and increases nitrogen use efficiency, being a slow release biofertilizer.

1.4.2 Other organic resources available in the region

Sugarcane trash, rice and maize straw are available but quantities are not easy to predict because of limited documentation. Factory ash is also a by-product of white sugar manufacture. It is obtained after the bagasse (remains of cane stalk after crushing) has been burnt to generate energy for steam production which is used for sugar processing. The amount produced annually is not documented and its use as biofertilizer is limited, perhaps due to its low nutrient content (0.11, 0.18 and 0.56 for total N(%), total P(%) and %K respectively), Appendix 3.

Farmers get animal manures from nearest feed lots or buy from fellow farmers with large herds of cattle. The use is common among farmers far away from sugar factories.

1.5 Justification of the study

There is a rising demand for filtermud as a biofertilizer among farmers in the sugar belt, hence the practice of using decomposed filtermud is not possible. Farmers are forced to apply the fresh material which has detrimental effects on crops. Decomposed filtermud was found to have a positive effect on nitrogen release since it has a narrow carbon to nitrogen (C/N) ratio 17.73 (Anyango, 1984). Hence, the study was proposed using other alternatives of curing to reduce the curing period so as to make the biofertilizer available to the farmers in the sugar belt at planting time.

1.6 Objectives of the study

The main objective of this study is to improve the filtermud quality so as to enhance nutrient release and reduce curing time in order to avail the product to the farmers at the right time. This would be achieved through the following specific objectives:

(a). Characterization of filtermud, factory ash and cattle manure.

(b). To conduct incubation studies to obtain nutrient release patterns from filtermud, factory ash and cattle manure.

(c). To estimate nitrogen uptake by a maize crop in a pot experiment under glasshouse conditions using filtermud amended with nitrogen.

CHAPTER 2

2.0 LITERATURE REVIEW

2.0.0 Cambisols

The soils are moderately well drained deep to a very deep reddish brown to dark reddish brown clay loam. They have ABC sequence of horizon developed from rhyolites and have gently undulating to rolling slopes (4 - 9%). According to Rachilo et al., (1984) these soils are classified as Dystric Cambisols (1974/75 FAO Legend) which has a USDA equivalent as Inceptisol.

2.1.0 Nitrogen

Of the major plant nutrients, nitrogen has received a lot of attention because: it controls the rate of crop growth and maturity. A deficiency or excess can drastically affect crop yields.

Table 1: Distribution of Nitrogen on the various spheres

Source		Nitrogen in gigagram atom
Atmospheric	N_2	2.8×10^8
	N_2O	130
Biosphere	plants (land)	570
	plants (ocean)	14
	animals (land)	15
	animals (ocean)	14
Hydrosphere	organic	2.4×10^4
	inorganic	7.1×10^3
Lithosphere	organic	5.7×10^7
	inorganic	1.4×10^7
Soil	organic	1.25×10^4
	inorganic	1.50×10^4

(Delwiche, 1983)

According to Table 1, nitrogen is widely distributed with the largest nitrogen reservoir represented by atmosphere. Nitrogen captured in the biomass represents small portions of total nitrogen in nature yet this biomass nitrogen is of vital importance. It may exchange quickly with nitrogen of atmosphere, hydrosphere and lithosphere.

2.1.1 Total nitrogen

Total nitrogen of soils range from less than 0.02% in the sub soils to greater than 2.5% in the peats. The surface layer of most cultivated soils contain between 0.06 % and 0.5% nitrogen (Bremner, 1965). Accumulation of soil nitrogen closely follows that of soil organic matter. In natural ecosystems, the nitrogen content of soils is in organic matter form. It is the interactions of environmental factors affecting the microbial activity and vegetation type that largely determine the nitrogen contents of soils (Haynes, 1986). Nitrogen can be maintained at high levels in the soils when microbial activity is inhibited at least for some period in a year, for example, activities of microbes can be inhibited by low temperatures, poor drainage, low pH, presence of toxic inhibitory substances and formation of organic matter complexes (Haynes, 1986).

2.1.2 Organic nitrogen

Of the total amount of nitrogen present in most surface soils usually a very large proportion constituted of organically bound nitrogen (above 90% of total nitrogen from the top soils). The fact that nitrogen is predominantly stored in soils in organic forms and is available to plants in inorganic forms is the basis for the profound interest that soil fertility specialists have shown since long for the interrelationship between these forms. The main groups of soil organic nitrogen are mainly: amino acids (20 - 50% of the total organic nitrogen), amino sugars (4 - 10% of the total organic nitrogen) and amines/amides (1 - 2%) (Bremner, 1965)

2.1.3 Inorganic nitrogen

Inorganic nitrogen usually amounts to a very minor proportion of the total soil nitrogen <2%, according to Melillo, (1981); Woodmansee et al., (1981), hence the reservoir of nitrogen that is potentially available for uptake by plants is mainly of organic nature. The process of mineralization being the turnover of nitrogen from organic to inorganic forms is therefore better understood than that of immobilization (Dehaan et al., 1976). The inorganic nitrogen forms in most soils for plant uptake are: ammonium (NH_4^+) and nitrates (NO_3^-), nitrites (NO_2^-) are sometimes detectable but the amounts are generally very small compared with the amount of ammonium and nitrates. Nitrites accumulates in alkaline soils after application of high rates of ammonium fertilizers because ammonium inhibits the oxidation of nitrite by nitrobacter species during nitrification (Bremner, 1965; Keeney et al., 1982).

2.1.4 Ammonium fixed in soil minerals

Fixed ammonium is defined as ammonium (NH^{4+}) that cannot readily be exchanged by other cations. Ability of soils to fix ammonium is due to occurrence of micaceous minerals. However, vermiculites have the greatest capacity to fix potassium and ammonium ions (Bajwa, 1982). Nommick, (1957) working with some Swedish soils concluded that a more realistic interpretation of equilibrium equation could be as follows:

$(NH_4^+ + K^+)s \leq (NH_4^+ + K^+)e \leq (NH_4^+ + K^+)\ f$

where s, e and f denote solution, exchange and fixed phases respectively. Rate of fixation is much greater than rate of release, thus fixed ammonium is unavailable for microbes and plants. Fixing capacity of soils does not exceed 10 meq/100g dry soil but in some a capacity of more than 15 meq/100g dry soil has been observed (Legg and Allison, 1959). Bremner, (1959) reported that fixing capacity of surface soils is less than in subsoil. This could be due to the fact that content of native fixed ammonium related to the total amount of nitrogen in subsurface soils is generally higher than in surface soils (Stevenson and Dhariwal, 1959).

2.2 Nitrogen transformation

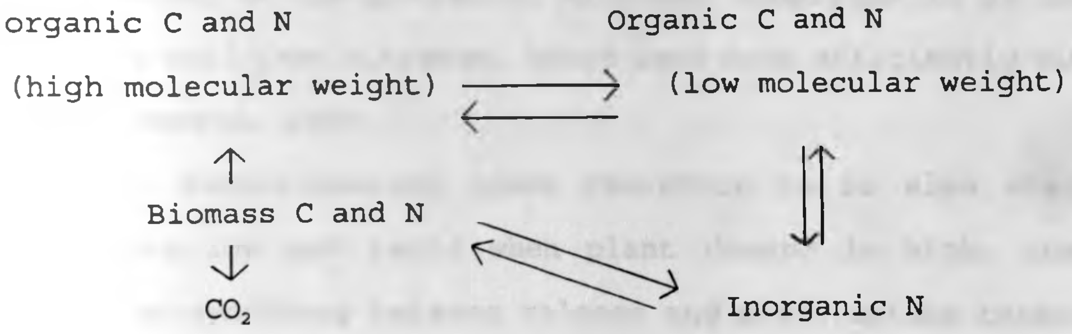
2.2.1 Nitrogen mineralization

Nitrogen mineralization denotes the overall process by which organic nitrogen is transformed into inorganic forms(NH_4^+ and NO_3-) as a result of microorganism under conducive environmental factors such as soil pH, temperature and moisture. Immobilization is the conversion of inorganic (NH_4^+, NO_3^- and NO_2^-) to organic forms due to synthetic reactions associated mainly with microbial growth and metabolism, such that elements become unavailable to the plants. Where as mineralization releases mineral nitrogen for plant uptake, immobilization prevents mineral nitrogen loss since it is incorporated in microbial biomass through synthetic reactions. Mineralization of decomposing residues is a major source of plant nutrients in highly weathered soils with little inherent mineral fertility (Sanchez et al., 1989).

Soil organic matter can be divided into active pool (labile fraction), slow pool and passive pool (humic substances) (Theng et al., (1989). The labile fraction of soil organic matter plays a key role in the maintenance of soil fertility as a source of plant nutrients due to its chemical composition (microbial biomass, carbohydrates, exocellular enzymes and particulate organic matter) and rapid turnover (0.2 - 1.4 years) for active pool and (8 - 50 years) for slow pool. The stable components are largely identifiable with humic substances whose stability is mainly due to their interactions with the mineral constituents and entrapments within clay aggregates, hence does not participate in mineralization process. Matus et al., (1994) reported nitrogen mineralization rates varying between 30 - 130 kg ha^{-1} per year; based on Chilean agro-ecosystems.

Energy and growth substances generated by heterotrophic metabolism are utilized to increase the biomass and hence nitrogen demand of decomposer population (Ladd et al., 1987), Figure 1. Soil microflora are prime decomposers of organic substrates contributing more than 90% of the net energy flux in soil and are the most important mediators of metabolic turnover of nitrogen .

Figure 1: Metabolic turnover of nitrogen and carbon.



(Ladd et al., 1987)

2.2.2 Importance of N-mineralization

In natural ecosystems most plant nitrogen is derived from mineralization of organic forms of nitrogen. Amino acid nitrogen contributes to mineral nitrogen derived from mineralization (Kai et al., 1977). Between 2.6 - 4.0% of nitrogen immobilized from nitrate and 1.4 - 3.7% immobilized from ammonium are mineralized each year in a growing crop of oats, thus mineralization rates have been estimated from below 2% per year to as high as 10%, Bartholomew et al., (1960), (cited in Bartholomew, 1965). Many soils contain nitrogen in the range of 0.05 to 0.01%, hence may release between 25 - 50 kgN ha^{-1} per year (Barber, 1984). Mineralization of organic compounds takes place in essentially three steps which include; amminization, ammonification and nitrification. Both amminization and ammonification are effected by heterotrophic micro-organisms especially the ammonifying bacteria. Ammonification is an important microbial process, not only because it supplies the raw materials for nitrification process but also provides a readily available nitrogen source for nitrogen source for cereals and grassland species: and it can also be regarded as the preferred nitrogen supply as it is less lost from the soil than nitrates, hence used more efficiently within the plant (Harris, 1989).

Net mineralization needs therefore to be slow when plants needs are low and rapid when plant demand is high: thus there should be synchrony between release and plant uptake because N use efficiency is to be enhanced within the agricultural systems. The rate of nitrogen release depends largely upon the following factors: quality and quantity of resource, moisture, temperature, soil factors such as texture, mineralogy and acidity, biological activity and presence of other nutrients (Myers et al., 1994).

2.2.3 Factors affecting mineralization

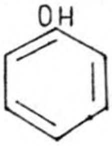
2.2.3.1 Substrate quality

Substrate quality includes concentration of various classes of organic compounds. The quality is the critical factor determining the rate of mineralization. Nitrogen content had been shown to be important factor controlling rates of decomposition in many studies (Yongberg, 1978; Melillo, 1980 (cited in Haynes, 1986); Myers et al., 1987; Mulongoy et al., 1993; Kachaka et al., 1993). Low quality materials are those containing less than 2% nitrogen and with a carbon to nitrogen (C/N) ratio greater than 25 (Yongberg, 1978). These materials would cause immobilization of soil nitrogen during their initial stages of decomposition in the soil. Conversely, high quality materials with greater than 2% nitrogen content and less than 25, C/N ratio would rapidly release nitrogen when incorporated in the soil. However, there are other modifying factors, for example, it has been demonstrated that the lignin concentration or lignin to nitrogen ratio provides an effective index for nitrogen release patterns (Melillo et al., 1984; Melillo et al., 1982). Fox et al., (1990) conducted a study using the shoots of many legumes and found that lignin content ranged from 42 - 111g/kg, nitrogen from 18 - 47 g/kg and polyphenols from 19 - 82 g/kg. Net nitrogen release after a 12 week incubation varied from 11 - 47% of that applied. He concluded that (Lignin + polyphenol) to N ratio was an excellent indicator of mineralization rate for the first 12 weeks after incorporation, however its use require a standardized method for plant polyphenol analysis.

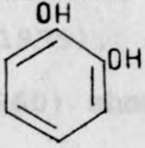
In another study Oglesby et al., (1992) found polyphenol: nitrogen ratio as the most important factor in controlling mineralization. She found that cumulative nitrogen was negatively correlated with polyphenol content for the early incubation period (Week 1 through week 8) and with lignin in later time periods (week 4 through week 12). Despite little correlation with nitrogen content alone, the relation with polyphenol to nitrogen ratio appeared stronger and more consistent than polyphenol alone. Tian et al., (1992a, b) for a range of tropical woody and herbaceous residues, found that decomposition was strongly correlated with nitrogen, lignin and polyphenol concentrations. In turn nitrogen mineralization was directly related to decomposition rate and the patterns of release of P, Ca and Mg were similar to that of N. Palm and Sanchez, (1991) examined a range of plant leaf materials to determine the variations in their concentration of N, lignin and polyphenols. They found that regression against the polyphenol/N ratio could explain 76% of the variation in nitrogen release.

Phenolic compounds are substances which have aromatic ring bearing a hydroxy substituent, including functional derivatives (esters, methyl ethers, glycosides etc) Harborne, (1989), example

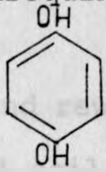
Phenol



Catechol



Hydroquinone



Although significant number occur in animals, most are of plant origin. Three important groups of phenolic polymer include: lignin, malanins and tannins. Phenols may be of importance in the resistance mechanism of plants phytopathogen (Goodman et al., 1986). They may also be of importance in chloroplasts and photosynthesis processes (Halliwell, 1984). Plant residues with high lignin/N ratio (Melillo et al., 1982)., low nutrients content and /or high polyphenol content (Palm and Sanchez, 1991) result in chemical recalcitrance with a greater proportion decomposing into stabilised soil organic matter (humic substances). Polyphenols form stable polymers with amino groups and nitrites through nitrosation (Palm and Sanchez, 1990, 1991).

2.2.3.2 Moisture

Moisture influences mineralization of nitrogen in three major ways; moisture stress inhibits microbial growth directly, high moisture content decreases aeration and microbial growth (Walters et al., 1992), and cycles of wetting and drying tend to increase amount of available substrate. At high moisture contents rates of biological activity and decomposition is decreased through lack of oxygen thus under anaerobic conditions decomposition depended on anaerobic bacteria. Mineralization is, however, positively correlated to soil moisture (Mazzarino et al., 1991; Odhiambo, 1989). Moisture availability may limit the catabolic capacity of micro-organism in the soil at water potential, below -10 to -50 bars (Swift et al., 1979).

Birch, (1958, 1960) showed that drying and rewetting released nitrogen from grass tissues added to an acid soil compared to no release of nitrogen under constant moisture conditions. Cycles of drying and rewetting generally cause flushes in nitrogen mineralization, with each successive cycle causing a slightly smaller flush and the size of the flush is positively related to humus content, the dryness of the soil and the length of time the soil remained dry. The most likely explanation to this effect is that rapid release of nitrogen results from the lysis of soil microbes exposed to a sudden change in water potential (Kieft et al., 1987). In order to survive and function at low soil water potential, the microbes accumulate osmotically active substances, thus decreasing their cell water potential (Yancey et al., 1982). When the soil water potential increased suddenly water moves into the cell faster than the organism is able to adjust its osmoticum, resulting into the rupture of the cell (Scholes et al., 1994). Between 17 - 70% of the soil microbial biomass can be lost in this fashion with each wetting event (Kieft et al., 1987).

2.2.3.3 Temperature

Temperature is a major factor influencing decomposition of organic materials. Nitrogen mineralization and soil respiration rates increased exponentially with soil temperature over a range of 10 to 30°C (Scholes et al., 1994). Mesophilic bacteria, actinomycetes and fungi have their optimum temperature range between 0 - 45°C and are common soil inhabitants. Thermophilic bacteria and actinomycete (45 - 60°C) and are minor soil inhabitants (Alexander, 1977). Temperature regime varies over earth surface on a latitudinal gradient modified locally by the aspect of the terrain (Swift et al., 1979). The amount of radiation entering the decomposer habitants of litter and soil is regulated by the extent of vegetation cover. Temperature also fluctuates seasonally and diurnally. These fluctuations are modified by other features of the litter and soil environment. Transfer of heat energy within the soil body is by conduction, since soil is poor conductor transfer of heat is slow. Consequently, fluctions in temperature is very marked at top surfaces but decrease in amplitude with depth. Decomposer population changes induced by temperature fluctuation is of great ecological significance. Example, thermophilic organism dominate the habitats during high temperatures and the mesophilies dominate at lower temperatures, hence thermophilic organisms maintain decomposer activity at high temperature and conversely mesophilic do maintain activity at lower temperatures.

2.2.3.4 Soil pH

The microflora and microfauna, living within water films at the surface of charged particle in the soil are most susceptible to the effect of variation in local pH (pH of the immediate environment). This pH is the determinant of microbial activity while the bulk pH (pH of a wider environment) is useful as indicator of microorganism distribution at a larger scale. The local pH of soil solution may effect the availability of essential elements to the decomposers because of variation in solubility and ionic form. Example, Iron precipitates out as insoluble hydroxide from ferric salt at pH 3 and ferrous salts at pH 5 (Swift et al., 1979). Production of inorganic nitrogen is greater in neutral than in acid environment because acidification tends to depress but not eliminate mineralization. Consequently treatment of acid soils with lime accelerates the decay of plant tissues, simple carbonaceous compounds and soil organic matter (Alexander, 1977; Lyngstad, 1992; Karuku, 1989; Stevenson (cited in Logan, 1992). In acid soils, hydrogen (H^+) and Al^{3+} ions tend to predominate at the colloid surfaces causing rise in acidity within the soil environment. This acidity hinders activities for most micro-organisms except a few like the fungi which are adopted to low pH values. With the additions of lime which contains mainly calcium (Ca^{2+}) ions the pH will be increased by Ca^{2+} ions replacing the Al^{3+} and H^+ ions at the colloid surfaces. The increased pH will improve the availability of nutrient elements and decomposer population is also modified, hence rate of mineralization increased as nitrifying bacteria and other related organisms increase in size.

2.2.3.5 Effect of time on mineralization

Depending on the quality of the organic materials used, mineralization is rapid within a few weeks of incorporation, for high quality materials or is slow and spread over several weeks for low quality materials, thus time is a function of quality. Rubaduka et al., (1993) working with woody legume prunnings found that at least 59% of the total nitrogen was released within two weeks of incorporation. Alexander et al., (1988), working with fresh and dry azolla under tropical conditions in two culture experiments, found that nitrogen released from 5 tons fresh and dry azolla per hectare, compared well with cattle manure and green leaves from week 6 to 8. At that level, the highest available nitrogen was 86.3% from fresh azolla at week 10, 78.0% from dry azolla at week 8, 59.6% from cattle manure at week 6 and 86.0% from green leaves at week 12. Weeraratna, (1979) working with some green manures in Tropical alluvial soil, found rapid release of ammonium and nitrates in the early stages of incubation, (week 4). Yokoyama et al., (1991) reported that readily decomposable organic N in cow dung mineralized rapidly during the first 5 days regardless of dung bettle activity.

2.3.0 Nitrogen uptake in plants

Both ammonium (NH_4^+) and nitrates (NO_3^-) are commonly present in soil solution and both are readily taken up by roots, and are absorbed by inducible energetically dependent uptake mechanisms. Predominant form of N available to plants is NO_3^- since under most soil conditions NH_4^+-N is rapidly nitrified to NO_3^--N (Haynes, 1986). Utilization of NO_3^- in plants include uptake, storage, translocation, reduction and incorporation of N into organic forms. NH_4^+ is major form under unfavorable conditions for nitrification processes, poor aeration and or soil acidity (Haynes, 1986). In well aerated soils with pH 6 to 8 plants absorb predominantly NO^{3-} which remain in solution and readily move to plant roots by massive flow of water. For example, Foth et al., (1988) estimated that 79% of nitrogen at root surfaces was there through massive flow, 20% through diffusion and 1% through interception. When plants absorb nitrogen mainly as NH_4^+ there is excess cation uptake compared with anion uptake and hydrogen (H^+) ion is excreted which decrease the pH in the rhizosphere. When uptake is mainly NO_3^- there is excess uptake of onions and OH^- ion is excreted which increase the pH of the rhizosphere. Depending on types of plants, some plants prefer NH_4^+ while others prefer NO_{3-} (Barber, 1984). Temperature and pH influence relative uptake ratio of NH_4^+ and NO_3^-, thus NH_4^+ absorption increased as pH increased while NO_3^- uptake decreased with increasing pH. Where both NH_4^+ and NO_3^- are present, absorption of NH_4^- is greater than NO_3^- at 8°C with NH_4^+ influx reaching maximum at a media temperature of 25°C. NO_3^- absorption also increased with temperature, becoming greater than NH_4^+. Other factors influencing the uptake of NH_4^+ and NO_3^- include competition among other cations and anions during active uptake (Haynes, 1986).

2.3.1 Synchrony of nutrient release and uptake in agro ecosystems.

Synchrony is the matching of the crop's demand for nutrients to the supply of nutrients by the soil and other sources, in both time and space. It is the key to improved nitrogen management (Myers, 1987). Organic inputs of low quality, (high C/N ratio, high lignin and ployphenol contents) would immobilize nitrogen upon incorporation into the soil, hence would release minimum amounts of nitogen for plant uptake. These low quality materials require more time to decompose. On the other hand, high quality materials (low C/N ratio, low lignin and polyphenol contents) would mineralize nitrogen easily upon soil incorporation, hence their nitrogen release can be synchronized with the crop demand.

In natural systems, nutrient release from litter and plant uptake of nutrients generally occurs in synchrony, resulting in efficient use of nutrients. However, in agro ecosystems, the two processes of release and uptake are separated in time, resulting in low nutrient use efficieny. This is true with nitrogen where excess amounts are lost through leaching, denitrification and ammonia volatilization (Sanchez et al., 1989). From a management view point, nutrient availability can be controlled to some extent by quantity, quality placement and timing of organic inputs, Sanchez et al., 1989; Swift, 1985 (cited in Sanchez et al., 1989).

2.4 Organic resources in the sugarbelt

There are numerous organic resources that could be used as organic fertilizers but the major ones within the Nyando sugar belt are grouped into two categories namely: off-farm and on-farm organic resources. The former category includes filtermud, cattle manure from feed lots, poultry manure from deep litter systems and factory ash while the latter category includes: maize and rice straw, farm yard manure, compost, sugarcane trash and limited amount of poultry and cattle manure.

Organic fertilizers are cheaper and more available than inorganic fertilizers and so most small scale farmers are able to purchase them, and they also improve soil physical conditions in addition to supplying the plant nutrients (Anon, 1978b; Poulin, 1980; Smaling, 1993). Crop residues contain nitrogen in organic form, therefore, decomposition followed by mineralization are a prerequisite of plant uptake. Conversely animal manure contains significant proportion of their nitrogen in inorganic form as NH^{4+}, Beauchamp, 1986 (cited in Rees et al., 1993).

Long term organic soil amendments increased biological activity in proportion to the amount of carbon added where as inorganic nitrogen application decreased biological activity but had limited or no effect on microbial biomass and enzyme activity (Fauci and Dick, 1994). They reported that it is possible to maintain adequate inorganic nitrogen to avoid plant nitrogen deficiencies during a transition from inorganic to organic nitrogen sources without inhibiting the establishment of a larger, more active microbial biomass. Goyal et al., (1992) also reported an increase in microbial biomass with continuous use of organic inputs than inorganic fertilizers.

2.4.1 Chemical and Physical properties of FM

Filtermud is the finest deposit obtained during the filtration and clarification processes of crushed canes. It is obtained after sugarcane juice has been filtered at filtering station in the factory. The mud at the filter machine comes out at a conveyor belt which then conveys it to a waiting truck for disposal at the dumping area. To aid in clarification, slaked-lime (Cao) is added to the juice, hence the end product (filtermud) is well saturated with calcium. Sulphur and phosphoric acid are also added to aid in clarification and pH maintenance.

Literature on its physical properties is limited (Anyango, 1984). However, particle size analysis done by Abu-Idris et al., (1979) showed that at one month it had the following composition: Coarse fibre (8%), fine fibre (20%) and non fibrous (>2%) : Six months later it was: coarse fibre (1%) fine fibre (10%) and non fibrous (89%) and twelve months after the start of observation the non-fibrous constituted 100%. Philpotts, (1976) reported 78% fibre, 11.6% mud solids, 78.80% water and 81% dry matter loss on ignition. The fresh materials have very high moisture content ranging from 65 to 75% (Donato et al., 1980).

There are increasing interests in its chemical properties because of the possibilities of using it as a biofertilizer. Although it contains low nutrients the quantities which are usually applied render it valuable as a fertilizer for nitrogen, phosphorus, potassium, calcium, and sulphur. It also increases soil pH and improved soil physical structure (Songambele, 1982).

The degree of decomposition influences the phyio-chemical properties of the material. One of these properties was the pH which was closer to neutral for most decomposed filtermud samples (Anyango et al., 1984). Fresh filtermud contain high levels of ash and exhibited high water holding capacities compared to decomposed filtermud which is higher in pH (pH 6.7 to 7.9) than fresh one (pH 5.3 to 7.0). The extractable phosphorus, organic carbon, carbon to nitrogen (C/N) ratio, calcium and magnesium levels are higher in fresh than in decomposed samples (Anyango, 1984). Total nitrogen levels in decomposed samples are higher than in the fresh samples, 1.44% and 1.06% N respectively, (Anyango, 1984). Therefore the C/N ratio of the fresh samples is wider (33.29) than in the decomposed (17.73) (Anyango, 1984). Kibunja, (1984) reported higher nitrogen content (8.8%) and low moisture content(23.09 %) for the filtermud. Data on filtermud from different sugar mills in Kenya and from other countries are given in Appendix 1.

Recent work done on filtermud chemical composition in Kenya indicated that there was variation in organic matter content, example Mutanda, (1978) reported 19.9%, while Anyango, (1984), 65.55% organic matter, Appendix 1. Also exchangeable potassium reported by Mutanda, (1978) was low compared with those values reported by Anyango, (1984) and Kibunja, (1984), Appendix 1. There is a wide variation in exchangeable bases between Kenyan filtermud and those from other countries especially calcium, where as Kenyan samples are well saturated with calcium, those from other countries have as low as 2.8% exchangeable calcium, Appendix I.

However, the amount of filtermud per unit of cane crushed and its composition vary greatly with the locality, variety, season and efficiency of the factory (Patil et al., 1983, Anyango, 1984: Songambele, 1982). Some of the reason for these variations includes: soil fertility and fertility regime adopted, climate conditions and harvesting methods as mechanically harvested cane had lower mud content than manually harvested (Paul, 1974).

2.4.1.2 Utilization of FM as a biofertilizer

Applications of 10 tha^{-1} of filtermud (6 and above months old) was found to be beneficial for rice grown in two successive seasons (Paramasivam et al., 1990). Gupta, (1989) reported that filtermud, did not increase soil pH rapidly, but was inexpensive and had beneficial effects on crop growth and yield due to its high organic matter content and presence of both macro and micro nutrients. Application of 30 tha^{-1} of filtermud improved physical conditions of soils (Songambele, 1982) and trace elements supply (Singh et al ., 1991). Gloria et al., (1974) found that the main macro nutrients present in filtermud was nitrogen in protein form: about 30% of phosphorus was present in organic form: and of the micronutrients, iron was most common, followed by manganese, zinc, copper and molybdenum. Using filtermud as soil dressing it was possible to grow sugarcane where soil pH was 8.7 and electrical conductivity (EC) > 40 mmho/cm. The cane sets germinated and established faster and the yields were more than doubled as compared to control (Kinyali, 1976). He reported that the effect of filtermud may be due to its high potassium content (13 meq/100g soil). There was a significant increase in cane yields when 20, 40 and 80 tons per hectare of filtermud were added but the sugar yields per hectare were not improved (Urgel et al., 1971). Filtermud is a useful fertilizer especially when applied to soil in which the top soil has been removed or redistributed for any reason, for example where soil drainage has been altered to accommodate mechanical harvesters (Blackburn, 1984).

Responses of crops to filtermud application especially maize are still not yet well documented although its use is well established. However responses of Sugarcane to filtermud application had been reported. Loscin, (1953) and Abi-Idris, (1979) reported a 27-45% increase in sugarcane yields when 50 tha-1 of filtermud (FM) was applied while Alexander, (1972) reported 27% yield increase when 50 tha^{-1} of FM was used. For economic analysis, Songambele, (1982) obtained an average of 36% yield increase when 50 tha^{-1} FM was used. He estimated average yield increase using the values reported by Abu-Idris, (1979) and Alexander, (1972).

2.4.2 Cattle manure as alternative organic resource.

Cattle manure and other livestock manure supply an estimated 30% of the nitrogen needs for crop production in the North Eastern U.S.A, hence it is an important source of nitrogen in livestock intensive regions, Bandel and Fox, 1984 (cited in Jokela, 1992). The chemical composition of cattle manure is influenced by diet, storage and handling conditions, Fassen et al., 1987 (cited in Murwira et al., 1993); Berger, (1962). These factors account for some of the variations in manure composition reported from different sources, Appendix 2. Fresh and aerobically decomposed manure have low nitrogen effect on the soil, whatever their source. This is because the fresh manure has a higher carbon to nitrogen ratio and would therefore decompose slowly on incorporation with the soil. The aerobically decomposed manure has lost significant amount of nitrogen through denitrification as aeration increases losses through oxygen supply, only anaerobically treated manure increased inorganic nitrogen content in the soil and thus had a fertilizer effect (Murwira et al., 1993; Bernal et al., 1992). However cattle manures have nutrients imbalance especially for phosphates and this requires correction through supplement soil treatment with phosphates (Brady, 1984). Nevertheless, like filtermud it remains a most valuable soil organic resource for resource poor small scale farmers. Crops do respond well to manure application, rates of 22.5 to 37.5 tha^{-1} can be made with little concern for adding toxic qualities of micronutrient (Brady, 1984). Upto 20 tha^{-1} is reasonable for maintaining soil fertility but above this rate, results in nitrate excesses and ground water pollution since high application rates lead to nitrate build up in the soil profile (Smith and Douglas, 1971). Animal manures are 3 to 4 times more effective than plant residues at increasing the labile pool of the soil organic matter because they have undergone the rapid initial decomposition phase (Smith and Douglas, 1971). Influence of manure application on leaf water potential and yields were more pronounced in sand and loam than in clay soil (Materechera et al., 1991). Okalebo et al., (1993) reported a significant grain yield increase from 1189 to 2639 kgha^{-1} in one instance due to the manure application in Makueni and Machakos Districts. They also reported that manure application resulted in greater residual benefits than did the inorganic fertilizers.

2.4.3 Sugarcane trash as alternative organic resource

Trash is the material left behind after cane harvest especially for green harvested cane, and not the burnt cane. In Australia there is a trend towards trash retention in sugarcane based on observation that green cane trash contains about 100 kg N/ha and that trash retention results in increased soil N within a singel crop cycle, Wood, 1986 (cited in Myers, 1987). In tropical areas at least where cane is grown, organic matter from trash retention is mostly gone with in six months to 12 months, however in Hawaii it was established that leaving the trash on the surface has three general effects, since the sun does not strike the soil directly, the soil remains cool and hence evaporation is reduced, that trash piled on the surface aid in control of weeds and preserves moisture (Clements, 1980). In the sugarcane growing regions like the Nyando sugar belt trash can be another source of organic resource. Although Clements, (1980) discourages its use as manure due to its short term effect farmers would benefit even if it means only six months or upto one year on fertilizer saving for a resource poor farmer.

2.4.4 Factory ash as alternative organic resource

Literature on factory ash is very limited (Songambele, 1982). However, due to its low nutrient composition, it is not used for crop production in the sugarbelt. Total nitrogen was very low about 0.11%, Appendix 3, while silica content was high 33.33 %. The high silica content is of agronomic importance as far as the rind (bark) of cane stalk is concerned, high levels of silica reduce susceptibility of the cane to lodging.

2.4.5 Other organic resources used by the farmers

Farm yard manure is the mixture of unconsumed stems and animal excreta trampled into the soil, left for over eight to ten months to decompose.The decomposed material is dug out of the boma(small enclosures),stored temporarily then finally transported to the field. The amount of dry manure that can be expected to be deposited in the boma has been estimated by workers at ILCA (P.N. de Leeuw, Pers. Comm.) at 1 ton per year per tropical livestock unit. Some of the chemical composition of farm yard manure and other wastes is given in Appendix 4a. Bhagat et al., (1991) reported higher percent water stable aggregates, high available water capacity, lower bulk density and higher hydraulic conductivity of saturated soils when farm yard manure was mixed with rice straw and soil incorporated for a period of 5 years. Five tons per hectare of farm yard manure has been shown to increase maize yields by about 200 kgha^{-1} (7% compared to control, (Anon, 1994). Qureshi, (1989) reported that combined nitrogen - phosphorus mixed with farm yard manure fertilization increased maize yields over the years by 80 - 95%. Ikombo, (1984) reported that application of farmyard manure at the rate of 8tha^{-1} appeared to give high and consistent yields, close to that obtained by applying the standard rate of mineral fertilizers (this was 40 kg ha^{-1} N and 17 $kgha^{-1}$ P), indicating that this could supply maize plants with enough nutrients. However, Kilewe, (1987) showed that 40 tha^{-1} of air dry farm yard manure yielded a crop at least as good as that from the highest input of fertilizer, which supplied $120kgha^{-1}$ N and $40kgha^{-1}$ P. Okalebo, (unpublished) reported a yield of $3084kgha^{-1}$ and $2212kgha^{-1}$ of maize for first and second season respectively when farmyard manure($20tha^{-1}$) was used over three sites (Kathonzweni, Kampi ya Mawe and Kimutwa). Farm yard manure had high ash content,high mineral N(over 80 ppm) and high extractable P(over 150 ppm) compared to the levels found in the soil, indicating that they are useful sources of these nutrients, (Probert et al., 1990).

Compost is decomposed material of plant residue. The materials has moderate levels of macro nutrients, (Appendix 4a). It is commonly used by farmers who live away from sugar factories.

Poultry manure are quite important near large towns where poultry is kept in deep litter systems, wood shaving are used as beddings in this system. The materials is quite rich in nitrogen and phosphates (Appendix 4a). Biannual application of this manure, 10 tha-1 produced better effect both on the soil and on immediate crop than control, for example, maize and potato yields were raised by 23-25% (Qureshi, 1977).

Maize and rice straw are also organic resources, maize straw is fairly low in nutrients as compared with other resources discussed earlier. If it is incorporated into soil there is nitrogen immobilization during initial stages of decomposition.

This could be avoided with addition of inorganic nitrogen to enhance mineralization. Rice straw is commonly used around Ahero irrigation scheme where rice is being grown on large scale.

2.4.6 Laboratory incubation

Incubating soil samples in polythene bags in the laboratory has been proved to give reliable inorganic nitrogen availed in a given season and this correlated well with crop performance, (Standford and Smith, 1972; Gasser et al., 1976). The method involves an incubation under either anaerobic or aerobic conditions. The latter conditions are relatively simple, so many replicates can be performed. It however, over estimates nitrate mineralization rates due to massive disturbance hence aeration of the sample. The polythene bags have advantage in that they allow an gaseous exchange and minimize water loss, (Mochoge and Beese, 1984). Gordon et al., (1987) in Ontario, Canada, working with forest floor material, showed that the thickness of polythene bags did not affect mineralization of nitrogen and thickness of polythene bags remained impermeable to water loss.

CHAPTER 3

3.0 MATERIALS AND METHODS

3.1.0 Collection of filtermud, factory ash, cattle manure and soil samples

Fresh filtermud samples were collected from three sugar factories (Muhoroni, Chemelil and Miwani) at hourly interval at the filter station in the factory in order to make a representative sample. Samples were bagged in 60 Kg gunny bags. Cattle manure was collected from the nearest farmer keeping a herd of cattle. Factory ash was collected from Muhoroni sugar factory in 60kg bag. Surface soil (0 - 20cm) were collected from National Sugar Research Centre on already ploughed site, at random then bulked to make one composite sample. Samples were air dried and ground to pass through 2 mm sieve and stored for physical/chemical analysis at National Agricultural Laboratories. Analysis were done on the samples following the methods described by Anderson and Ingram, (1993).

3.1.1 pH and electrical conductivity

Fifty millilitres of distilled water was added to 20 g of sample, ratio (1:2.5). For filtermud and factory ash samples, the ratio was 1:5 (20 g sample 100 mls water) in order to have good paste as (1:2.5) ratio could not produce good paste. The mixture was shaken for 10 minutes using Universal Table Shaker, then left to stand for 30 minutes, and pH (water) of the supernatant liquid measured. After 1 hour the electrical conductivity of the Supernatant solutions with pH >6 was determined in order to identify the samples which were saline. For samples whose electrical conductivity >1.0mS/cm, saturated paste extract conductivity was determined; in order to find out the level of salinity: 300 g of factory ash and filtermud (Muhoroni and Chemelil) samples were weighed into plastic containers. Distilled water was added while stirring until it was nearly saturated. The mixture was left overnight, then transferred to the Buchner filter funnel with Whatman No.42 filter paper, vacuum was applied and filtrate collected whose conductivity was measured against the standards (1.412 and 12.900 mS/cm). Samples with pH <6 (soil and Miwani filtermud) had their pH (KCl) determined following the same procedure above to determine the level of acidity.

3.1.2 Particle Size Analysis (Texture)

Fifty grams of soil was weighed into 500 ml heat resistant bottle. To this 50 mls of distilled water was added; followed by 10 mls of hydrogen peroxide (10%). Hydrogen peroxide was continuously added until no reaction took place. To complete the reaction the container and the mixture was placed in hot water bath, then allowed to cool. To this calgon solution (40 g sodium hexametaphosphate with 10 g anhydrous Na_2Co_3 in 5 litres of distilled water), 20 mls was added and the mixture mechanically shaken overnight, then the contents transferred into 1000 mls sedimentation cylinder, by adding the water washings and making the volume to the mark with distilled water. The cylinders were allowed to equilibrate for 30 minutes, then mixed vigorously with a plunger and the stop watch started the moment the plunger is removed. Bouyoucos hydrometer readings were taken at 40 sec, 5 hr and again after 5 hr together with the temperature reading.

Calculation

% sand = 100 - 40 sec (corrected)

% silt = 40 sec (corr.) - 5 hr corr. % clay = 5 hr (corr.)

Then using USDA textural classification, textural class for the soil sample was determined.

Note:

40 sec (corr.) = 2 (40 sec reading - 40 sec blank + T)

5 hr (corr.) = 2 (5 hr reading - 5 hr blank + T)

T = temperature corrections; for every °C above 20°C (d), T =0.3 x d ; for every °C below 20°C (d), T = -0.3 x d.

3.1.3 Water content of soil

One gram of fresh sample was weighed into a dry container of known weight (W1). Total weight of sample plus container was recorded (W2), then dried in the oven at 105°C for 2 hours (Anderson and Ingram, 1993), allowed to cool then weighed (W3).

Calculation:

$$\text{Water content (\%)} = \frac{W2 - W3 \times 100}{W3 - W1}$$

3.1.4 Exchangeable bases (K^+, Na^+, Ca^{2+} and Mg^{2+})

Exchangeable bases were determined using ammonium acetate method described by Anderson and Ingram, (1993). A small plug of cotton wool was placed at the bottom of a leaching tube followed by a layer of 5 g acid washed sand mixed with 5 g sample. Another plug of cotton wool was again placed on top of the mixture to prevent excessive drainage. The leaching tubes were placed on the rack and 250 mls volumetric flasks placed below. Using measuring cylinder 25 mls of ammonium acetate (1M at pH 7) was added in 10 mls aliquots for over 2 hours, each time leaving the first aliquot to drain before adding another one. When the leaching ceased the content were made upto 250 mls mark with distilled water, and mixed and covered with stoppers. The leachate was used for bases. Potassium and sodium ions were determined using the flame photometer method while calcium and magnesium ions were determined using atomic absorption spectrophotometer as described by Anderson and Ingram, (1993).

Calculation:

$$\text{Meq M+ per 100 g soil} = \frac{\text{Extract Volume (mls) x 0.1x Meq per litre}}{\text{soil weight(g)}}$$

where M+ is the exchangeable Cations

3.1.5 Exchangeable acidity (Al^{3+} (H^{+})

This was done on samples with PH < 6 (soil and Miwani filtermud). 10 g of samples was weighed into 100 ml beaker. To this 25 ml of 1M potasium chloride was added, the mixture was stirred then left for 30 minutes and filtered through Buchner funnel with 5 successive 25 mls aliqouts of 1M potassium chloride. Five drops of phenolphthalein solution was added to the filtrate and titrated with 0.1 M sodium hydroxide to the first permanent pink end point. Blank of sodium hydroxide titre in 150 mls potassium chloride solution was used for correction:

Calculation

Exchangeable acididty (meq/100g) = (ml NaOH sample - mlNaOH blank) x 10

3.1.6 Total nitrogen and phosphorus

0.2 g of sample was weighed into digestion tubes and 4.4 mls of digestion mixture was added; (40 mls of blank digestion mixture was digested for standard compensation). The mixture was digested for 2 hours at 360°C until the solution was colourless; then allowed to cool and mixed with 50 mls of distilled water. The volume was made up to the mark with distilled water and the mixture was left overnight as described by Anderson and Ingram, (1993)

(a) Total Nitrogen

This was determined using Kjeldahl and steam distillation method described by Anderson and Ingram, (1993).

(b) Total Phosphorus

This was done using Olsen and Dean, (1965) method for extractable phosphorus. 1 ml of sample solution was pipetted into a test tube, and to this 4.0 mls of ascorbic acid solution was added; followed by 3.0 mls molybdate reagent and then well mixed. The mixture was left for 1 hour for full colour development and their standards and sample absorbance read colorimetrically.

3.1.7 Total organic carbon

This was done based on Nelson and Sommers, (1982) method. 0.1 g (manure samples) or 0.5 g of soil samples was weighed into labelled 100 ml digestion tube. 2 mls of distilled water was added; followed by 10 ml of 5% potassium dichromate solution then the solution allowed to wet the sample completely. 5 ml H_2SO_4 was slowly added from a slow burette and the mixture swirled and digested at 150°C for 30 minutes. After cooling, 50 mls of 0.4% barium chloride was added, the mixture was swirled to mix thoroughly and allowed to settle overnight to allow supernatant solution to form. Two blank tubes (with reagents but without extracts) were prepared. One of the blank tubes was heated and another unheated. The tube contents was then quantitively transferred into labelled 100 mls conical flasks and 3 drops of indicator (1:10 phenanthroline - ferrous complex) was added. Using a magnetic stirrer to ensure proper mixing, all samples and blanks were titrated against acidified ferrous ammonium sulphate solution to the end point colour (brownish red). Prior to titration the acidified ferrous ammonium sulphate was standardized to avoid oxidation in order to establish Molarity (M).

<u>Calculation:</u>

$$\% \text{ C} = \frac{\text{A} \times \text{m} \times 0.003}{\text{g}} \times \frac{\text{E}}{5} \times 100$$

where $\text{m} = \frac{0.4}{\text{T}}$

T = standardized titre
M = Molarity of ferrous ammonium sulphate (0.033m)

$$\text{A} = \frac{(\text{mls HB} - \text{mls sample}) \times (\text{mls UB} - \text{mls HB})}{\text{mls UB}} + (\text{mls HB} - \text{mls sample})$$

g = dry sample mass
E = extraction volume (mls) (50 for above procedure)
S = digest sample volume (4 for above procedure)
UB = Unheated blank
HB = Heated blank
% Organic matter =1.72 x % C (Anderson and Ingram, 1993)

3.1.8 Trace elements

Five grams of sample was weighed into conical flask and 50 mls of 0.1N HCL was added. The flasks were shaken for one hour and centrifuged at 2000 rpm for 10 minutes and supernatant liquid decanted (Anon, 1980). The mixture was filtered into 250 ml volumetric flask, then volume made up to mark with distilled water. Percent content of the trace elements (Zinc, Iron and Copper) were determined by Atomic Absorption Spectrophotometer (AAS).

Calculation

% element=graph reading(ppm)xinitial dilution(250mls)xdilution factorx10
in question weight of sample x aliquot taken x 10^6

3.1.9 Cation Exchange Capacity (CEC)

Five grams of sample mixed with acid washed sand was weighed into leaching tube already fitted with cotton wool. Another layer of cotton wool was fitted at the top surface of leaching tubes placed on round bottomed plastic bottles to drain. To this, 33 mls of 1 M sodium acetate was added twice. The mixture was washed with 20 ml 80% ethanol and the filtrate discarded. The washing with alcohol was done twice. To this, 33 mls of 1 M ammonium acetate was added twice and the filtrate collected into 100 ml volumetric flask. The volume of volumetric flask was made up to mark with distilled water and sodium concentration in the flask was determined by flame photometer.

Calculation:

$$1 \text{ meq Na/100g} = \frac{23}{1000} \times \frac{10^6}{100}$$
$$= 230 \text{ ppm.}$$

3.1.10 Polyphenolics

The following method was adopted from King and Heath, (1967).

0.1g (W) of material was weighted into a 50 ml beaker and 15 mls 50% methanols was added. Then the mixture was covered with paraffin to prevent volatilization of methanol then placed in a water bath at 77°C for 1 hour. Quantitatively the mixture was filtered through whatman No 1 filter paper into 50 mls volumetric flask using 3 mls of 50% methanol to rinse and volume made up to mark with distilled water, 1 ml of unknown solutions or standard was pipetted into 50 ml volumetric flask, 2.5 ml of Folin cioclateus reagent (phenol reagent) was made up to the mark, and the mixture rested for 20 minutes for colour development, thereafter the standard and unknowns were read at 760 nm in spectrophotometer.

Calculation

$$\text{Total extractable polyphenol (\%)} = \frac{CX5}{W}$$

Where: C = corrected concentration
W = weight of sample (g)

3.1.11 Lignin via acid Detergent Fibre (ADF)

Acid detergent fibre is prepared from sample by boiling with a sulphuric acid (0.5 M) solution of cetytrimethyl ammonium bromide (CTAB) under controlled conditions. The CTAB dissolves nearly all the nitrogenous compounds and acid hydrolyses the starch leaving a residue containing lignin, cellulose and ash. Lignin is removed by oxidation with a buffered permanganate solution and cellulose is determined by weight loss upon ashing, (Van Soest and Wine, 1968).

One gram of samples were weighed into 250 ml round bottom flasks with a round glass joint to fit a reflux condenser (W_1). To each sample 100ml of sulphuric acid/CTAB solution and a few drops of anti-foam agent were added then the condenser was connected then refluxed for 1 hour. The mixture was filtered through crucible of known weight (W_2) under gentle suction and residue washed with 3 x 50 ml aliquots of boiling water. Again the residue was washed with acetone until there was no colour change, then sucked dry. The residue was oven dried for 2 hours at 105°C, cooled and reweighed (W3).

Calculation:

$$\text{Ash containing ADF (\%)} = \frac{\underline{W3 - W2} \times 100}{W1}$$

The crucibles containing the dried acid detergent fibre were then placed in a shallow enamel pan containing cold water (1 cm depth). To each sample 25 mls of combined permanganate/buffer solution was added and water level adjusted to 2 - 3 cm in the pan to reduce flow of solution out of crucibles. Glass rod was used to break-up the lumps and to draw the solution onto the sides of the crucibles to ensure uniform wetting of particles. The mixture was allowed to stand for 90 minutes at room temperature and more combined solutions added if necessary to maintain the purple colour. The mixture was then filtered under suction. The crucibles were placed in a clean pan and half filled with demineralizing solution until it was white. The mixture was again filtered and washed thoroughly with 80% ethanol, then washed with acetone and filtered. The crucibles were then dried for 2 hours at 105°C, cooled and reweighed (W4). The contents of the crucibles were then ashed at 500°C for 1 hour, cooled and weighed (W5).

Calculation:

$$\text{Lignin (\%)} = \frac{W5 - W4}{W1} \times 100$$

3.2 Laboratory incubation

Laboratory aeration method of incubation was adopted in this study as described by Anderson and Ingram, (1993). Dry samples were ground and passed through 2 mm sieve to remove large particles. The treatments were;

Muhoroni fitermud (FM)	Chemelil FM	Miwani FM
Muhoroni FM+N	Chemilil FM+N	Miwani FM+N
Muhoroni FM+ factory ash(FA)+N	Chemilil FM+FA+N	Miwani FM+FA+N
Muhoroni FM+FA	Chemilil FM+FA	Miwani+FM+FA

Cattle manure and factory ash alone or incombination with mineral N were included to make a total of 15 treatments in split plot arranged in Complete Randomized Design(CRD) with three replicates. The ratios for FM and FA in the mixtures were constant at 4:1 by weight; (300g FM, 75g FA) respectively and mineral N was added to mixtures at a rate of 9 kg/ton of FM as calcium ammonium nitrate according to Foth et al., (1988). The treatments (15) above were in sub plot while the time of sampling was the main effect.

The treatment mixtures were brought to field capacity using distilled water (Anderson and Ingram, 1993). Sub-samples (5g) of the mixture were removed at time 0, for determination of mineral nitrogen through the steam distillation method (Bremner, 1965). The polythene bags were tied off and incubated at 26°C with, sampling at 2 weeks interval for a period of 12 weeks.

3.2.1 Measurements of NH_4^+ and NO_3^+

The extraction procedure involved the use of 50 mls 1M KCL added to each plastic bottle with 5 g of sample and the mixture shaken for 1 hour, then rested for 20 minutes; following Bremner, (1965) method as described by Anderson and Ingram, (1993). The supernatant solution was filtered using filter paper No.4 and a minimum of 20 mls was collected. To determine NH_4^+ and NO_3^-, 0.2g of MgO was added to the mixture then distilled to liberate ammonia which was collected in boric-acid-indicator solution and determined by titration with 0.01 HCL. Second distillation was done on the mixture after addition of Devadar's alloy to reduce ammonium to nitrates.

Calculation:

Net mineralization was calculated as the difference in mineral nitrogen between any two time periods (time 1 - time 0) and results expressed as % nitrogen released in 14 days.

% N released of the total added = X/Y x 100

where X = nitrogen released per treatment (g).

Y = total N added in the material

3.3 Nitrogen uptake by maize in pot experiment.

Nitrogen uptake by maize (H512) was determined in plastic pots (H 6cm, D 16cm), well perforated for ease of drainage. The treatments were:

Soil(3kg) alone
Soil(3kg) + 15 tha^{-1} FM + N
Soil(3kg) + 30 tha^{-1} FM + N
Soil(3kg) + 100 kg Nha^{-1}

Soil(3kg) + 45 tha^{-1} FM + N   Soil(3kg)+ 7.5 tha^{-1} Filtermud (FM)

The design of the experiment was a split plot arranged in Complete Randomised Design with four replicates. The Miwani FM was chosen because it was superior in terms of nitrogen release than Muhoroni or Chemelil FM from results obtained in the laboratory incubation experiment. Nitrogen was added at a rate of 9 kg/ton of FM in the form of CAN. The treatment above were in the subplot while time of sampling was the main effect. All pots (standing on plastic dishes to avoid nutrient loss) received 3 kg soil (same soil as above), ground and sieved to pass through 5 mm sieve. In addition to this all pots received phosphates at 50 kgPha^{-1} as basal dressing in the form of single super phosphates to correct for phosphate deficiency as these soils were deficient in P(3.67ppm). Potassium levels were moderate, hence needed no supplementation. The contents of the pots were thoroughly mixed and four maize seeds were planted, then pots watered to 42% field capacity (Anderson and Ingram,1993), which was maintained through regular monitoring of weight loss, and water was added to make up for the weight loss. After emergence, the seedlings were thinned to two plants per pot.

Destructive sampling was done at interval of 3 weeks for a period of 9 weeks. At harvest two plants from each pot were cut at ground level oven dried for 48 hours at 80°C, weighed to get biomass, and finely ground for mineral nitrogen analysis, following semi-macro Kjeldahl method (Bremner, 1965). The remains of pot contents were discarded. The roots were not sampled to avoid mechanical errors as they were forming a densed mat and could easily break and remain in the soil.

Calculation

$$\text{Total N(\%)} = \frac{T \times S \times 0.01}{A \times W}$$

where
T = corrected titre (mls)
S = final digest solution volume (mls)
A = aliquot volume (mls)
W = sample weight (g)

Nitrogen uptake (%) = %N x Biomass

% nitrogen uptake of total added:

$$\text{\% nitrogen uptake} = x/y \times 100$$

where x = nitrogen uptake per pot (g)
y = total nitrogen added per pot (g)

CHAPTER 4

4.0 RESULTS

4.1 Chemical and physical properties of soil, cattle manure filtermud and factory ash.

The soil was moderate to strongly acid, moderate in sodium and potassium but poor in calcium and magnesium (Anon,1984). It was also poor in nitrogen and phosphorus but moderate in micro-nutrients. The soil textural class is a sandy clay loam with low organic carbon content,(Anon,1984) about 1.2 % (Table 2). According to Rachilo et al., (1984) the soil was classified as Dystric Cambisol based on FAO-UNESCO legend.

Fresh filtermud had moisture content ranging from 65 - 72%, the pH for both cattle manure and factory ash were moderate to strongly alkaline (pH 8-9), (Table 3a). Organic matter content for all the filtermud samples ranged from 38 - 54%, whereas cattle manure and factory ash had 36.5% and 56.8% organic matter, respectively. Carbon contents for all filtermud samples, cattle manure and factory ash were high (>20%). Total nitrogen was low in filtermud ranging from 0.5 - 0.87%, whereas cattle manure had high nitrogen content, 1.3% (Table 3b) and factory ash had 0.22% N. The carbon to nitrogen (C/N) ratios for all filtermud samples were greater than 35; cattle manure had C/N ratio of 16 while factory ash had the highest ratio of 150 (Table 3b). All filtermud samples were moderate in phosphorus (>10 ppm), similarly cattle manure and factory ash were also moderate in phosphorus. All filtermud samples were well saturated with bases especially calcium (>100 meq/100g), similarly cattle manure and factory ash were also high

Table 2: <u>Physical and chemical properties of soil from sugar Research Centre, Kibos (0 - 20cm)</u>

Particle size analysis	
%sand	68
%silt	8
%clay	24
Textural class	Sand clay loam
pH Water (1:2.5)	5.70
pH HCL (1:2.5)	4.70
OM %	2.10
Carbon %	1.20
Total N %	0.13
C/N ratio	9.20
Extra. P (ppm)	3.67
Exch. Bases (meq/100g)	
Na	0.60
K	0.88
Ca	2.10
Mg	1.22
CEC (meq/100g)	4.80
Fe{ }	1.62
Cu{ppm)}	4.00
Zn{ }	6.00

in bases especially calcium. The cation exchange capacities (CEC) were high for both filtermud, cattle manure and factory ash samples, (Table 3a).

All filtermud samples were high in lignin content (>10%), cattle manure had 26 % whereas factory ash had the highest lignin content of 42% (Table 3b). The polyphenol content was low in all filtermud samples, cattle manure and factory ash; 0.19% (Table 3b). Lignin to nitrogen ratio ranged from 19 - 26 for filtermud samples and cattle manure but highest in factory ash which was 190. Similarly; lignin plus polyphenol to nitrogen ratio ranged from 20 - 27 in filtermud and cattle manure but highest in factory ash of 191. Lastly, polyphenol to nitrogen ratio was low in both filtermud, cattle manure and factory ash as shown in (Table 3b).

4.2 Effect of filtermud, cattle manure and factory ash on nitrogen release (mg/g) over 12 weeks incubation period.

Treatment (FM + N - Miwani) gave significantly ($P \leq 0.05$) higher nitrogen than the rest of the treatments. It gave a total of 7.41 mg/g, Table 4(a). The two treatments namely, FM + N - Muhoroni and FM + N -Chemelil released about 6.2 mg/g of nitrogen. Treatment FM + FA +N - Miwani followed with 5.1 mg/g nitrogen released, Table 4(a). Treatments FM + N - Chemelil and FM + FA +N -Muhoroni were not significant ($P \geq 0.05$) in terms of nitrogen release, they released about 4.5 mg/g nitrogen, Table 4(a). Cattle manure was superior to FM alone or in combination with FA, it had about 2.88 mg/g nitrogen released. This was followed by factory ash ammended with mineral nitrogen releasing about 1.98 mg/g nitrogen Table 4(a). However, FM alone or in combination with factory ash were not significant ($P \geq 0.05$) with about 0.2 mg/g nitrogen released, on the average. Factory ash recorded the least nitrogen release.

Table 3(a): Chemical properties of filtermud, Cattle manure and factory ash

	Moisture content %	pH H_2O (1:2.5)	pH KCl	extra. P (ppm) (1:2.5)		Exch. bases			CEC meq/100g
					Na	K (meq/100g)	Ca	Mg	
Muhoroni FM	72	7.17	-	13.99	1.56	2.04	158.5	14	85
Chemelil FM	65	7.70	-	15.26	1.48	1.88	146.0	15	94
Miwani FM	70	5.00	4.93	12.23	1.44	2.84	109.5	18	87
Cattle manure	7.06	9.27	-	12.16	2.96	2.04	8.3	12.6	76
Factory ash	1.7	8.35	-	10.37	1.88	2.04	66	5.8	65

Where FM - filtermud

Table 3(b): **Biological properties of filtermud, Cattle manure and factory ash**

	OM %	C %	Total N %	C/N ratio	L %	PP %	L/N ratio	L + PP/N ratio	PP/N ratio
Muhoroni FM	54.9	31.9	0.85	37.5	20.59	0.19	24.22	24.45	0.22
Chemelil FM	56.1	32.6	0.87	37.5	17.23	0.19	19.8	20.04	0.22
Miwani FM	38.4	22.3	0.5	45.4	13.47	0.19	26.94	27.32	0.38
Cattle manure	36.5	21.3	1.3	16.4	26.05	0.19	20.04	20.18	0.15
Factory ash	56.8	33	0.22	150	41.93	0.19	190.59	191.45	0.86

Where FM - filtermud

C/N - carbon to nitrogen ratio

PP - polyphenols

L - lignin

The highest N release by any single treatment occured at week 4 with a mean of 0.62 mgN/g. This was followed by week 2 which had 0.54 mg/g nitrogen released, Table 4(a).

Considering the percent nitrogen released of the total added, Table 4(b), treatment FM+N Miwani was again superior to the rest of the treaments with about 53% nitrogen released. This was followed by treatment FM+FA+N Miwani with 44% nitrogen released. Treatments FM+N-Muhoroni and FM+N-Chemelil were not significant with about 34% nitrogen released, Table 4(b). Similarly treatment FM+FA+N-Muhoroni and FM+FA+N-Chemelil were not significant in terms of nitrogen released, Table 4(b). However, the least percent nitrogen released was recorded with treatment FM+FA-Chemelil giving about 14.1% nitrogen released as opposed to factory ash alone.

Regression analysis of nitrogen release versus the quality of the material used showed that there was a negative linear relationship between %lignin content (r = -0.99) and nitrogen released. Percent lignin to nitrogen, carbon to nitrogen, lignin + polyphenol to nitrogen ratios also showed significant negative linear relationships with nitrogen release, Table 5. However, nitrogen and polyphenol contents did not have effect on nitrogen release, since their values were very low.

Table 4 (a): Effect of filtermud, cattle manure and factory ash on nitrogen release (mg/g)

	Time (weeks)							
Treatment	2	4	6	8	10	12	total	mean
Fm (muh)	0.23	0.25	0.23	0.20	0.22	0.20	1.33	0.22^{g}
Fm (chem)	0.13	0.28	0.24	0.24	0.24	0.20	1.33	0.22^{g}
Fm (miw)	0.20	0.18	0.13	0.19	0.14	0.13	0.97	0.16^{g}
Fm+N (muh)	1.18	1.25	1.14	0.98	0.82	0.81	6.18	1.03^{b}
Fm+N (chem	1.02	1.12	1.08	1.02	0.96	0.94	6.14	1.02^{b}
Fm+N (miw)	1.34	1.41	1.20	1.14	1.17	1.15	7.41	1.24^{a}
Fm+Fa+N(muh)	0.89	0.98	0.70	0.65	0.68	0.68	4.58	0.76^{d}
Fm+Fm+N(chem)	0.84	0.96	0.74	0.74	0.57	0.55	4.40	0.73^{d}
Fm+Fa+N(miw)	0.99	1.02	0.83	0.69	0.79	0.78	5.10	0.85^{c}
CM	0.32	0.82	0.54	0.51	0.32	0.37	2.88	0.48^{e}
FA +N	0.37	0.37	0.32	0.33	0.28	0.31	1.98	0.33^{f}
FA	0.06	0.06	0.06	0.06	0.06	0.06	0.36	0.06^{h}
FM+FA (muh)	0.21	0.25	0.21	0.19	0.21	0.19	1.26	0.21^{g}
Fm+FA (chem)	0.20	0.17	0.17	0.17	0.16	0.17	1.04	0.17^{g}
Fm+FA (miw)	0.17	0.13	0.13	0.13	0.09	0.12	0.78	0.13^{g}
Total	8.15	9.26	7.72	7.24	6.71	6.66		
Mean	0.54^{b}	0.62^{a}	0.51^{c}	0.48^{d}	0.48^{d}	0.44^{e}		

CV(a) = 16.6%
CV(b) = 14.4%
SE (time) = ±0.0094
SE (treatment) = ±0.0052
LSD (1%) time = 0.018

Where (Muh) - Muhoroni
(Chem) - Chemelil
(Miw) - Miwani
FM - Filtermud
FA - Factory ash
CM - cattle manure

Treatments with same letters indicate no significant difference at probability level (5%) by DMRT

Table 4(b): Effects of filtermud, cattle manure and factory ash on nitrogen release (% nitrogen release of the total nitrogen added)

Treatments	Total N added(g)	N-released (g)	%N released
FM(Muh)	2.60	0.399	15.35
FM(Chem)	2.60	0.399	15.35
FM(Miw)	1.50	0.291	19.40
FM+N(Muh)	5.30	1.854	34.98
FM+N(Chem)	5.30	1.842	34.75
FM+N(Miw)	4.20	2.223	52.93
FM+FA+N(Muh)	5.47	1.718	31.40
FM+FA+N(Chem)	5.47	1.650	30.52
FM+FA+N(Miw)	4.37	1.913	43.76
CM	3.90	0.864	22.15
FA+N	3.36	0.594	17.68
FA	0.66	0.108	16.36
FM+FA(Muh)	2.77	0.473	17.06
FM+FA(Chem)	2.77	0.390	14.08
FM+FA(Miw)	1.67	0.293	17.51

Where FM (Muh) - Muhoroni filtermud
FM (Chem) - Chemelil filtermud
FM (Miw) - Miwani filtermud
N - Nitrogen
FA - Factory ash
CM - Cattle manure

Table 5: Correlation coefficients (^{r}) of Lignin, % nitrogen content, carbon to nitrogen (C/N) ratio and lignin to N ratio on nitrogen release (%)

Source	Nitrogen released(g)	% L content	%N total	C/N ratio	L/N ratio	PP content(%)	PP + L/N ratio	PP/N ratio
Factory ash	0.35	41.93	0.22	150.0	190.60	0.19	191.45	0.86
Filtermud (chem)	1.07	17.23	0.87	37.5	19.80	0.19	20.02	0.22
Filtermud (Muh)	1.11	20.47	0.85	37.5	24.22	0.19	24.45	0.22
Filtermud (Miw)	1.18	13.47	0.50	45.4	26.94	0.19	27.32	0.38
Cattle manure	0.87	26.05	1.30	16.3	20.04	0.19	20.18	0.15
R^2 (%)		97	19	72	86	-	87	1
r		-0.99**	0.43NS	-0.85**	-0.93**		-0.93**	-0.1NS
Sample size(n) = 30								
$P \leq 0.01$								

Where L - lignin
PP - polyphenols
N - nitrogen
C/N - carbon to nitrogen ratio
Chem. - Chemelil
Muh. - Muhoroni
Miw. - Miwani

4.3 Response of maize to filtermud application in a greenhouse experiment.

(a) Dry matter production (g/pot)

Where the 45 tha^{-1} FM and nitrogen were added a significantly $(P\leq 0.01)$ higher dry matter than the rest of the treatments was obtained. About 2 g of dry matter per pot was obtained at week 3 which reached a maximum of 19 gDM/pot at week 9, Figure 2. Treatment soil + 30 tha^{-1} FM+N followed next with maximum dry matter production of 12 g/pot at week 9. Treatments soil alone and soil + 7.5 tha^{-1} FM were not significant $(P\leq 0.01)$ in their dry matter production throughout the period (week 3 - 9). Both had the lowest dry matter accumulation reaching 4 g/pot at week 9, Figure 2.

(b) Nitrogen uptake (mg/g) per pot.

Treatment soil + 45 tha^{-1} FM+N was significantly $(P\leq 0.01)$ superior to the rest of the treatments in terms of nitrogen uptake. It had accumulated a total of about 0.82 mg/g of N per pot taken up by plants over the period, Table 6. This value was about 6% greater than the control (soil with no ammendment), Table 7. Treatment soil + 30 tha^{-1} FM+N followed with a total nitrogen uptake of 0.6 mg/g N per pot and was about 3% greater than the control, Tables 6 and 7. Treatment soil + 100kgNha^{-1} and soil + 15 tha^{-1} FM+N did not have significant$(P\geq 0.01)$ difference in nitrogen uptake throughout the period. They had a total of about 0.4 mg/g nitrogen taken up by the plants and this value was about 2% greater than the control, tables 6 and 7. However, there was a depression in nitrogen uptake in treatment soil+7.5 tha^{-1} FM when compared with the control. Maximum nitrogen uptake was at week 6 and this value was significantly $(P\leq 0.01)$ higher than that at week 3 and 9. There was no synchrony between nitrogen release and uptake because maximum release was at week 4, while maximum uptake was at week 6; Table 4a, 6.

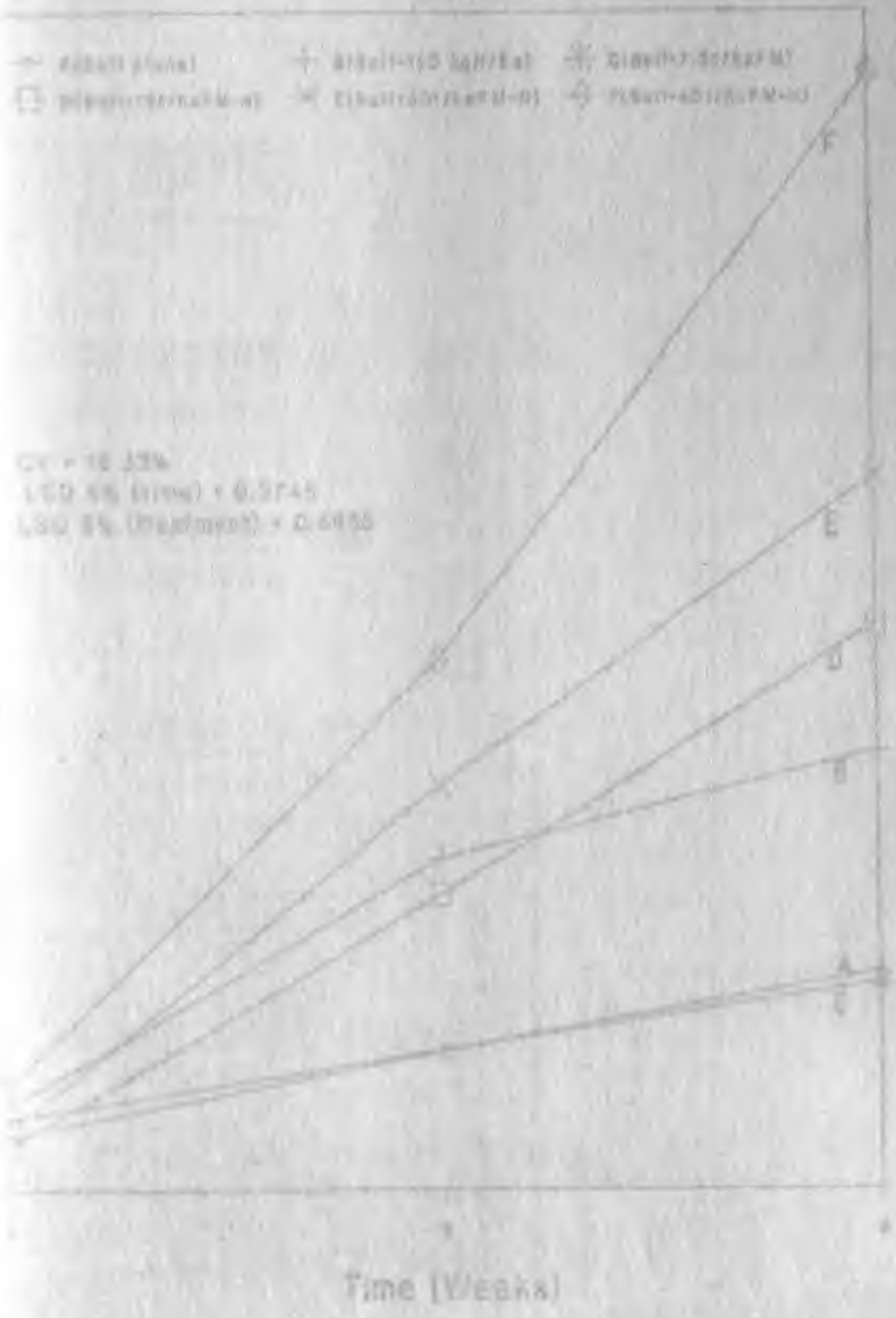


Fig. 2: Maize dry matter production (g/pot) at various N levels (mean of 2 plants)

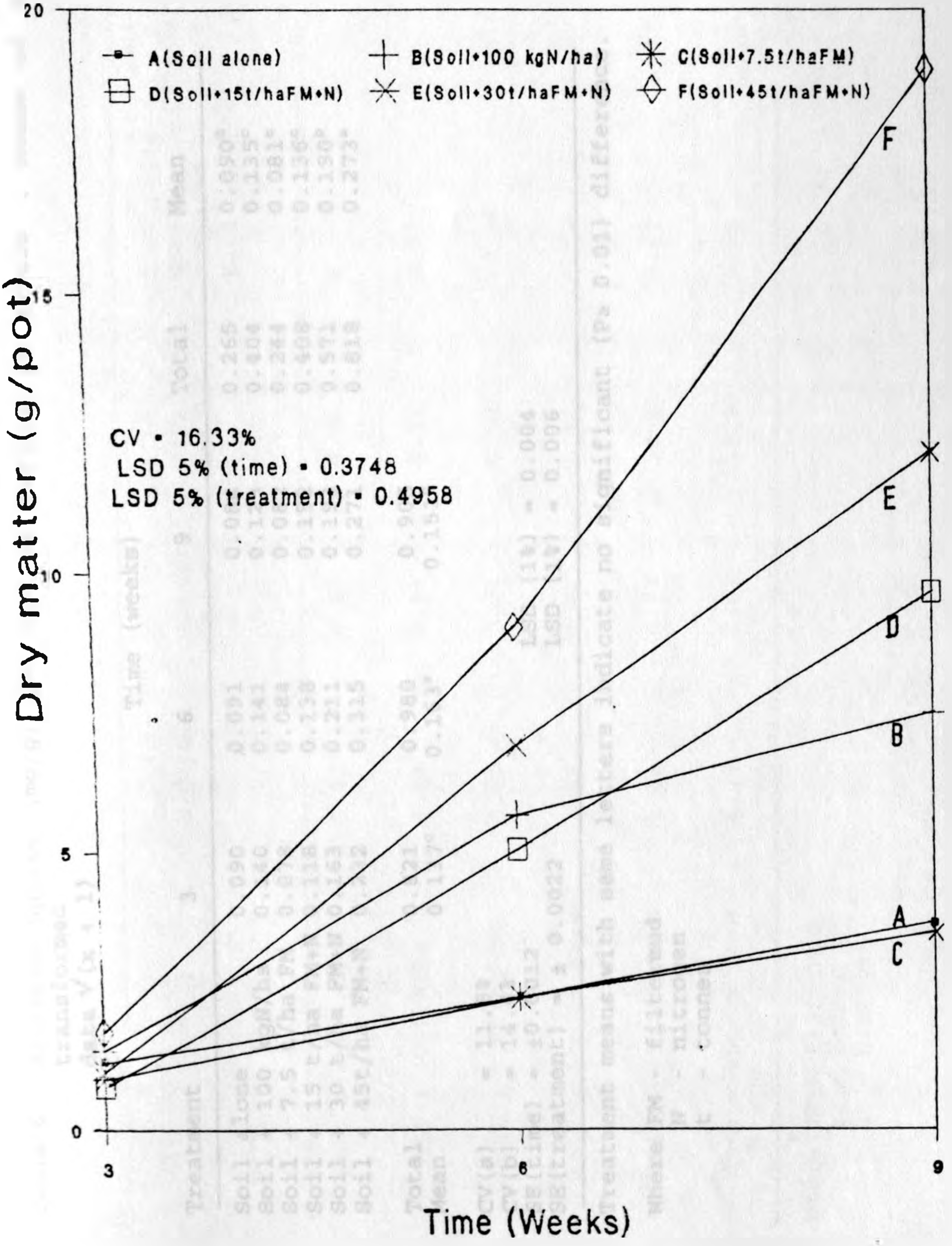


Fig. 2: Maize dry matter production (g/pot) at various FM levels (mean of 2 plants)

Table 6: Nitrogen uptake (mg/g) per pot at various FM levels (Means of 2 plants) transformed data $\sqrt{(x + 1)}$

	Time (weeks)				
Treatment	3	6	9	Total	Mean
Soil alone	0.090	0.091	0.084	0.265	0.090^{d}
Soil + 100 kgN/ha	0.140	0.141	0.123	0.404	0.135^{c}
Soil + 7.5 t/ha FM	0.078	0.084	0.082	0.244	0.081^{e}
Soil + 15 t/ha FM+N	0.118	0.138	0.152	0.408	0.136^{c}
Soil + 30 t/ha FM+N	0.163	0.211	0.193	0.571	0.190^{b}
Soil + 45t/ha FM+N	0.232	0.315	0.271	0.818	0.273^{a}
Total	0.821	0.980	0.905		
Mean	0.137^{c}	0.163^{a}	0.151^{b}		

CV(a) = 11.8%
CV(b) = 14.4%
SE(time) = ±0.0012 LSD (1%) = 0.004
SE(treatment) = ± 0.0022 LSD (1%) = 0.006

Treatment means with same letters indicate no significant ($P \geq 0.01$) difference.

Where FM - filtermud
N - nitrogen
t - tonnes

Table 7: % nitrogen of the total added to the soil

Treatment	total N(g/pot)	N uptake (g/pot)	% nitrogen uptake	% nitrogen uptake compared with control
Soil alone	3.90	0.27	6.92	0
Soil + 100kgN/ha	4.44	0.41	9.23	2.31
Soil + 7.5t/ha FM	3.95	0.24	6.08	-0.84
Soil + 15t/ha FM+N	4.69	0.41	8.74	1.82
Soil + 30t/ha FM+N	5.48	0.57	10.40	3.48
Soil + 45t/ha FM+N	6.27	0.82	12.92	6.00

Where FM - filtermud
t - tonnes
N - nitrogen

CHAPTER 5

5.0 DISCUSSION

5.1 Chemical and physical properties of soil, cattle manure, filtermud and factory ash.

These results were similar to those found by Rachilo et al., (1984) and Thorp et al., (1960) except for pH and CEC; Table 2 which were rather low from this study because of effect of leaching of bases with time. Cambisols are moderately weathered soils with no argillic B-horizon, they are developed from rhyolites or granites (acidic parent materials) hence have low inherent fertility. Ssali et al., (1986) reviewed that soils developed from acidic parent materials like granites and rhyolites have low inherent fertility while those developed from basic parent materials such as basalt and dolerites have moderate to high inherent fertility. Consequently, the soil needs intensive management through the use of both organic and inorganic fertilizers. Similar recommendation was made by Rachilo et al., (1984) and Thorp et al., (1960) in order to improve these soils of Nyando sugarbelt. The use of organic manures can help in the build up of organic matter, the key factor in maintaining soil productivity (Anon, 1978; Swift et al., 1991; Larson et al., 1972) as well as supplying available nutrients for plant uptake.

Moisture content for filtermud were similar to those reported by Mutanda, (1978) and Songambele, (1982). The pH results were also similar except for Muhoroni FM which Anyango, (1984) reported to be slightly acidic for the fresh samples. Differences in pH is a result of differences in use of additives like phosphoric acid used for juice clarification. However, there is a variation in organic matter content; Mutanda, (1978) reported 19.9%, Songambele, (1982) reported an average value of 37.8% while Anyango, (1984) reported values greater than 30%; Kibunja, (1984) reported 39.7%. Also there is variation in exchangeable bases especially calcium; whereas the Kenyan filtermud is well saturated with calcium, filtermud in other countries is deficient in calcium. The variation may have been due to differences in soil fertility and fertilizer regime adopted (Songambele, 1982). For example, the low potassium content of Mumias filtermud could be attributed to low potassium content of Mumias soils. The efficiency of the factory also influences the filtermud quality because different factories use different quantities of lime which later contribute to the high or low calcium content of filtermud; hence high or low cation exchange capacities. Kibunja, (1984) reported a lower cation exchange capacity(13.5 Meq./100 g soil),perhaps it was due to the fact that decomposed samples might have lost the bases through leaching compared to the fresh filtermud samples, which were used in this study, as was evident from high CEC values for fresh filtermud samples.Other factors contributing to filtermud variability are: harvesting fresh/green cane verses burnt cane, as the latter results into poor quality filtermud because burning removes some elements in gaseous forms(viz, sulphur as sulphur dioxide).

Crop variety also affects filtermud because fibrous varieties contribute to voluminous material with poor quality. Similarly, season affects filtermud quality as cane harvested during rainy season is full of mud which contributes to voluminous material.

Cattle manure was rich in nitrogen and had a low carbon to nitrogen (C/N) ratio. Materechera et al., (1991) reported nitrogen content of about 2.67% and C/N ratio of 15.1; Fauci and Dick, (1994) reported N-content of 1.5% with C/N ratio of 24. Other researchers (Anon, 1978a) had reported nitrogen content as low as 0.3%. However, the variation in nitrogen content and overall chemical composition of cattle manure depends on the diet, storage conditions, the species of animals and others (Smith and Douglas, 1971).

Nitrogen content of factory ash is low, 0.11% as reported by Songambele, (1982) while 0.22% nitrogen was recorded in this study. The high carbon to nitrogen (C/N) ratio of 150 and lignin content, 41.93% in the factory ash could explain its low popularity among farmers in the sugarbelt, because it decomposes very slowly upon incorporation into the soil. It may also result in nitrogen immobilization due to artificial nitrogen deficiencies.

5.2 Effect of filtermud, cattle manure and factory ash on nitrogen release (mg/g) over 12 weeks.

The source of filtermud did not affect the nitrogen release. This was evident from the lack of significant differences in nitrogen release of filtermud from the three factiories. However, when filtermud was ammended with nitrogen, Miwani filtermud became superior in terms of nitrogen release. The slightly lower lignin content obtained from Miwani filtermud could explain its superiority, despite its high carbon to nitrogen ratio.It was likely that during sample collection from Miwani Sugar factory, young cane low in lignin was being crushed because the factory resumed operation in early 1990. Treatments involving FM + FA + N were inferior to FM + N in this study. Donato et al., (1980) reported that fresh filtercake in combination with factory ash in a 4:1 ratio by weight cured in 25 days through bacterial and fermentative or enzymatic reactions. The inferiority of treatments involving the factory ash is probably due to the high lignin contents in the latter thus forming stable polymers with amino groups and nitrites (Palm and Sanchez, 1990,1991). Nevertheless, the peak nitrogen release was at week 4 which was comparable to 25 Mwys reported above. Similar results were reported by Weeraratna, (1979). The superiority of treatments FM+N over other treatments could be explained by the fact that mineral nitrogen improved FM quality.

Cattle manure was inferior to FM+N in terms of nitrogen decomposable organic-N, hence it must have undergone rapid initial decomposition during storage, hence loss of nitrogen through leaching. Same views were expressed by Smith and Douglas, (1971); Yokoyama et al., (1991). Quality of animal manures is influenced by storage and handling conditions.

FM alone or in combination with factory ash were not significanly different because fresh FM had high C/N ratio, therefore, low quality resulting into low nitrogen release. Likewise FM in combination with factory ash resulted into a low quality material, since factory ash had high carbon to nitrogen ratio and lignin content. Addition of factory ash to FM did not improve the quality of filtermud in order to enhance nitrogen release due to the high carbon to nitrogen ratio and high lignin content.

Regression analysis of nitrogen versus quality of material used showed that there was a negative linear relationship (r = -0.99) between % lignin and nitrogen release, which showed that the higher the lignin content in the material the lower the N released. The significance of lignin to nitrogen, polyphenol + lignin to nitrogen ratios was due to lignin content itself since the polyphenol and nitrogen contents were too low to have effects on nitrogen release. These results were similar to those reported by Melillo et al., (1982, 1984). However Palm and Sanchez, (1990, 1991) reported polyphenol content or polyphenol to nitrogen ratio to be important in N release when leguminous materials were used. Similarly, the carbon to nitrogen ratio effect on nitrogen release was significant, the higher the ratio, the lower the release. Same views were reported by Youngberg, (1978); Mulongoy et al., (1993); Kachaka et al., (1993).

The N mineralization results were comparable to those reported by Fauci and Dick, (1994). They reported that 36% of organic nitrogen originally added in form of poultry manure was mineralized after 87 days. Sims, (1986); Castellanos and Pratt, 1981 (cited in Fauci and Dick, (1994)) found that 28 - 48% nitrogen was released in an incubation study using fresh and composed poultry manure for periods ranging from 70 - 90 days. Franzluebbers et al., (1994) estimated that 24% and 27% nitrogen was mineralized from 5 and 7 weeks old cowpeas plants respectively. In this study, ammending filtermud with nitrogen improved its quality through lowering of the C/N ratio leading to increased nitrogen release(24%).

5.3 Pot experiments in the greenhouse

(a) Maize dry matter production

The superiority of soil + 45 tha^{-1} FM + N over the rest of the other treatments was expected because dry matter production increased with the amount of nutrients available. The inferiority of treatment, soil + 100 kgNha-1 over the organic material treatments is explained as probably due to rapid uptake of N from soluble (CAN) at early stage of maize growth, whereas N release was slow but readily available over a long period of FM + soil treatments. However, lack of significant difference between control and soil + 7.5tha^{-1}FM, showed that filtermud at 7.5 tha^{-1} (farmers practice) was not supplying enough N to influence the the dry matter production, it is therefore uneconomical for the farmers to continue applying this rate. Increase of dry matter with time was expected because of increase in size as plants grew.

(b) Nitrogen uptake (mg/g) per pot

Treatment, soil + 45 tha^{-1} FM was superior to other treatments.Like in the dry matter production, nitrogen uptake is also influenced by it's availability such that FM + soil treatments were superior to soil + 100Kg Nha^{-1} treatments because the latter had nutrients in available forms which were exhausted faster than the former. Curve B had a higher slope which later declined while those curves involving soil + filtermud (ammended with N) had their slopes increasing. Depression in N uptake in treatment soil + 7.5 tha^{-1} FM (non ammended FM) compared to the control could be due to nitrogen immobilization, as was evident from maize plants which were stunted and showed yellowing which is a symptom of nitrogen deficiency. Nitrogen uptake was significantly ($P \leq 0.01$) reduced at week 9 than at week 6. The rapid increase in nitrogen uptake between week 3 and 6 was attributed to protein synthesis, as the season progressed the rate of nitrogen uptake declines due to reduced protein synthesis activity as plants mature (Maobe and Chweya, 1992).

The peak nitrogen release was at week 4 from the incubation studies, whereas the highest nitrogen uptake was at week 6. This showed that there was no synchrony between the release and uptake, and this is important because losses through leaching, volatilization and denitrification could be enhanced. The peak demand for maize nitrogen uptake is in the vegetative phase which varies from 22 to 46 days when mean temperatures ranges from 27°C to 15°C respectively, CIMMYT (cited in Fischer and Palmer, 1984). However, since the filtermud is a slow release biofertilizer, the nutrient release and uptake can be synchronized by incorporating it into soil at ploughing and later top dressing with mineral nitrogen. Mutanda, (1978) reported that instead of ammending filtermud with nitrogen at ploughing it could be incorporated into soil at ploughing and at 1½ months later mineral nitrogen be used for top dressing, for sugarcane.

However, the highest % nitrogen uptake was about 13% of FM + N, this was rather low compared with 20 - 30% of total peavine and poultry manure N, respectively which was added in two applications to the soil and was taken up by four maize crops as reported by Fauci and Dick, (1994). High quality materials like peavine and poultry manure release more nitrogen for plant uptake than the slow release low quality fresh filtermud.

If 13% of nitrogen was released in 9 weeks, it meant that the remaining 87% N remained in organic form and contributed to residue N which was to be slowly released with time. Also, low quality materials like FM result in chemical recalcitrance with greater proportion decomposing into stabilized soil organic matter (Humic substances) (Melillo et al., 1982; Palm and Sanchez, 1991).

Tissue nitrogen content was used in estimating nitrogen uptake instead of determining the soil available nitrogen at each growth stage.

CHAPTER 6

6.0 CONCLUSION AND RECOMMENDATIONS

6.1 Conclusions

The soil, Cambisol was low in fertility (moderate to strongly acidic, poor in calcium, magnesium nitrogen and phosphorous). Lignin content (%) was a major factor affecting the nitrogen release from filtermud, factory ash and cattle manure. An, r^2 value (97%) showed that there was a negative linear relationship between the % lignin and nitrogen release. The higher the lignin content, the lower the nitrogen release. Since Miwani filtermud had relatively lower lignin content compared with Chemelil and Muhoroni filtermud it was superior in terms of nitrogen release (53% over 12 weeks incubation period) than the rest of the treatments, and was thereafter used in pot experiment in the greenhouse for nitrogen uptake and biomass production. Miwani filtermud ammended with mineral nitrogen at 45 tha^{-1} was superior in terms of biomass production (19 g/pot) and nitrogen uptake (13%) over 9 weeks. There was no synchrony between the nitrogen release and uptake because maximum release was at week 4, while maximum uptake was at week 6. This could be avoided by incorporating fresh FM in soil at ploughing and later (1½ months) top dressing with mineral nitrogen, to enhance release, hence nitrogen uptake.

6.2 Recommendations

The soil used in the above study is a Cambisol which is of low inherent fertility. Therefore addition of 45 tha^{-1} FM ammended with nitrogen at 9 kg/t of filtermud to improve its fertility is necessary. Small scale farmers who are situated away from sugar factories (>20 kms) could be adviced to use other organic resources which are available like animal manure, farm yard manure, compost and others, to avoid transportation costs.

Further research involving field trials using filtermud ought to be done as the above findings were based on controlled greenhouse conditions; hence may not relate well to field environment. Economic rates of filtermud and crop yields need to be determined so that a comprehensive economic analysis would be done to benefit Nyando sugarbelt farmers.

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Appendix 1: Chemical composition of filtermud

Source	pH water	pH CaCl,	Organic C(%)	Exch. Ca meq/100g	Organic matter (%)	Exch. cation Meq/100g)			Total N %	Extra.P (ppm)	C/N ratio	CEC (Meq/100g)
						Mg	Na	K				
Mutanda, (1978) Kenya	-	-	-	27.7	19.9	-	-	0.36	0.83	0.77	22.9	-
Kibunja, (1984) Kenya	5.3	5.1	23.09	-	39.7	-	-	-	2.61	-	8.8	13.5
Anyango, (1984) site (miw) Kenya	F-5.2	4.9	35.56	151.00	61.48	11.00	1.04	12.42	0.83	14.45	-	-
	D-7.9	7.6	22.95	127.00	39.68	5.00	1.04	10.42	1.15	9.19	-	-
Anyango, (1984) Site (Muh) Kenya	F-55.6	5.4	37.92	142.00	65.55	11.00	0.87	10.17	1.06	11.62	-	-
	D-7.3	7.2	20.46	126.00	35.38	4.00	0.71	14.65	1.38	6.95	-	-

Source Songambele, (1982)	Moisture content (%)	Organic matter (%)	%Carbon	Total N (%)	Total P (%)	Avail. P (%)	Avail. P%	% Ca	% Mg	% S	% Si	Cu	Zn	Mn	Fe	Bo	Al	Moly
												--------- (ppm) -------------						
Dymond, (1923) S. Africa	-	63	-	1.06	-	0.63	-	-	-	-	4.7							
Anon, (1942) S. Africa	-	-	-	0.81	-	1.10	0.16	9.77	0.79	-	4.3							
Loc Sin, (1953) Philippines	-	-	-	2.01	-	1.50	-	0.23	2.3	-	-							
Locsin, (1953) Hawaii	68.39	-	-	0.37	-	0.35	-	-	-	-	-							
Lugolopez, (1953) P. Rico	60-80	20-30	-	1.13	-	1.09	0.56	2.59	1.43	-	-							
Alexander, (1971) S. Africa	74.8	-	-	0.43	0.23	0.18	0.05	0.46	0.09	0.05	-	-	13	17	226	-	-	-
Alexander, (1972) S. Africa	-	63.96	37.1	1.93	1.02	0.19	0.20	1.51	0.41	4.40	-	46	60	681	-	-	-	-
Prasad, (1974) Trinidad	-	-	-	1.71	-	0.45	0.48	1.97	0.70	-	-	28	224	2450	5000	-	-	-
Abu-Idris et al., (1979) Trinidad	73	68.96	40	1.41	1.25	0.92	0.51	2.32	0.37	-	-	55	366	1840	3440	-	-	-
Cooper et al., (1980)	-	-	-	1.33	-	1.01	0.47	2.09	0.40	-	-	50	350	1800	3500	-	-	-
Wood, (1981)	-	68.10	39.5	1.52	1.07	0.93	0.29	2.23	0.47	0.51	-	64	114	1191	10500	-	-	-
Mean values	71.55	57.8	38.9	1.22	1.01	0.74	0.33	2.8	0.57	1.53	4.5	43	189	1365	5610	-	-	-

Appendix 2: **Chemical composition of cattle manure**

Source Author and Year	Moisture %	Total N(%)	Organic Carbon(%)	C/N ratio	Avail. P(mg/kg)	Avail. K(mg/kg)	Extra. Ca (mg/kg)
Materechera *et al.*, (1991)	4.21	2.67	41.77	15.1	0.74	1.59	3852
Buchman, (1972)	-	0.5	-	-	0.25%	0.15%	-
Anon, (1978)	-	0.3	-	-	0.11%	0.08%	-
Fauci and Dick, (1994)	-	15gkg^{-1}	365gkg^{-1}	24	-	-	-

Appendix 3: **Chemical composition of factory ash**

Source	%Al	%Mn	%Mo	Total N(%)	Total P(%)	Avail. P(%)	%K	%Ca	%Mg	% silicon	%Fe
Maclean, (1976)				-	-	0.053	0.15	0.03	0.03	-	-
Maclean, (1976)				-	-	0.09	0.09	0.04	0.04	-	-
Wood , (1981)				0.11	0.18	0.11	0.56	0.31	0.34	-	-
Lushiku, (1981)	1.0	0.15	1.78	-	0.41	-	6.8	5.4	0.18	33.33	5.46
Mean values	1.0	0.15	1.78	0.11	0.3	0.08	1.89	1.45	0.15	33.33	5.46

Appendix 4a: Chemical composition of manures and various wastes

Manure source	pH	avail.Nmg/kg	moisture %	%C	%N	P_2O_5%	K_2	CaO (%)	MgO (%)
Farm manure	-	-	38-54	-	1-2.7	0.4-1.5	1.2-8.1	0.3-2.7	0.3-1.4
Poultry manure	-	-	10-13	-	2.3-2.5	2.3-3.9	1.0-5.7	0.6-4.0	0.9-1.6
Compost	-	-	49-52	-	0.5-1.6	0.3-0.5	5.0-7.4	4.6-5.4	-
Straw (maize stover)	-	-	-	-	0.5-0.6	0.1	3.7-4.7	0.3-0.4	0.2
Source: Qureshi, (1977)									
Sallade, (1992) (Poutry manure)	8.7	18879	58.7	-	55				
Goyal *et al*., (1993) (FYM)			28.0	1.6	0.22				
FYM (Boma manure)									
Ikombo, (1984)					1.62	0.5	1.34	-	-
Probert *et al*., (1992)					0.23-0.7	0.8-0.26	0.68-1.60	-	-
Mugwira and Shimba, (1986)					1.02	0.16	1.23	0.53	-
Mokwunye, (1980) Range for various samples from West Africa					0.48-1.95	0.06-0.57	0.39-2.62	-	-
Okalebo, (unpub.)					1.07	0.32	2.28		
P.N. de Leeuw (ILCA) (Pers. Comm.)									
Fresh Manure					1.28	0.45	2.65	1.26	-
Old cattle manure					0.49	0.31	1.65	0.85	-
Small stock manure					0.59	0.57	0.57	1.76	-

Appendix 4b: Lignin and Polyphenol contents reported by other workers

Author and Year	Material	%Lignin	Polyphenol
Beuchamp *et al.*, (1989)	Plants (general)	5-35	
	Maize straw	13.5	
Tian *et al.*, (1992)	Maize stover	6.8	0.56
	Rice straw	5.2	0.55
	Leucaena	13.4	5.02
	Gliricidia	11.6	1.62
	Acioa	47.6	4.09
Palm and Sanchez, (1990)	Gliricidia	7.8	1.02
	Leucaena	5.2	2.94
Fauci and Dick, (1994)	composed Beef manure	28.4	

Appendix 5: Effect of filtermud, cattle manure and factory ash on nitrogen release (ANOVA TABLE)

source of variation	Degree of freedom	Sum of squares	Mean squares	F value
Time	5	0.107	0.021	26.25**
Error (a)	12	0.009	0.0008	
Treatment	14	4.319	0.311	518.33**
Time x Treatment	70	0.154	0.002	3.33*
Error (b)	168	0.108	0.0006	
Total	269	4.697		

CV (a) = 16.6%
CV (b) = 14.4%

Appendix 6: Dry matter production (g) per pot at various FM levels (means of 2 plants) Analysis of variance table

Source of variation	Degree of freedom	Sum of squares	Mean squares	F values
Time	2	773.13	386.565	586.8406***
Error(a)	9	5.929	0.659	
Treatment	5	487.988	97.598	135.2079***
Time x Treatment	10	325.483	32.878	45.1459 ***
Error(b)	45	32.483	0.722	
Total	71	1625.408		

CV = 16.33%

SE(±) time = 0.1657

SE(±) treatment = 0.2453

SE(±) interaction = 0.4248

Appendix 7: Nitrogen uptake (Mg/g) per pot at various FM levels (means of 2 plants) Analysis of variance table)

Source of variation	Degree of freedom	sum of squares	Mean squares	F values
Time	2	0.0002	0.0001	5.00**
Error(a)	9	0.0002	0.00002	
Treatment	5	0.019	0.004	200
Time x treatment	10	0.0008	0.00008	4.00**
Error(b)	45	0.001	0.00002	
Total	71			

CV(a) 11.2%

CV(b) 11.2%

SE(Time) = ± 0.0012

SE(treatment) = ± 0.0022